U.S. Department of Transportation

Federal Aviation Administration

Operational Evaluation Report

for the

DFW Multisensor Fusion

Runway Status Light System (RWSL)

Takeoff-Hold Lights (THLs)

OPERATIONAL EVALUATION REPORT

APPROVAL SIGNATURE PAGE

RWSL

APPROVAL SIGNATURES		
PARTICIPANT	NAME	DATE
[RWSL Project Organization]		
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1 General Description of Operational Need

The Federal Aviation Administration (FAA) is dedicated to the goal of enhancing runway safety while ensuring airport capacity. The reduction of runway incursions has been identified as one of the most important aviation safety initiatives and is crucial for the improvement of runway safety.

Runway status lights may offer a means of reducing the severity of runway incursions and preventing runway accidents. They do so by indicating to pilots and vehicle operators that a runway is unsafe for entry or crossing or that a runway is unsafe for departure, thereby improving situational awareness.

2 Operational Concept

The Runway Status Light System (RWSL) is designed to be an all-weather automatic system providing safety backup to controllers, pilots, and vehicle operators by improving situational awareness via a visual alert indication to the pilots and vehicle operators in the runway environment. RWSL is not intended to increase controller workload nor decrease airport capacity, but rather works in concert with existing and new pilot procedures to enhance runway safety. The lights are driven automatically using computer processing of integrated surface and terminal surveillance information. Surface and terminal surveillance detects the presence and motion of aircraft and vehicles on or near the runways. The RWSL safety logic then assesses any possible conflicts with other surface traffic, illuminates red runway-entrance lights (RELs) if the runway is unsafe for entry or crossing, and illuminates red takeoff-hold lights (THLs) if the runway is unsafe for departure. The system turns the lights off automatically as appropriate when the runway is no longer unsafe. One goal of runway status lights is to reduce the number of runway incursions without interfering with the safe and orderly conduct of daily ATC and airport operations.

Runway-entrance lights (RELs) are in-pavement fixtures situated at selected runway-taxiway intersections and face the taxiways that intersect runways. RELs illuminate red when the runway is unsafe to enter; they are off otherwise. For each high-speed operation, RWSL software determines the status of the aircraft i.e., departure or arrival, and defines a safety zone in front of the aircraft. RELs for runway entrances that lie within that safety zone are illuminated to alert and help prevent aircraft or vehicles from entering at that position. To avoid interference with fundamentally safe operations, the RELs are extinguished just before the high-speed operation clears the intersection, when it is safe to start motion into the intersection, allowing controllers to use anticipated separation.

Takeoff-hold lights (THLs) are situated at selected full-length and intersection takeoff-hold positions. THLs are also in-pavement fixtures, installed alongside the runway centerline for approximately 1000 feet facing aircraft in the takeoff hold position. This configuration is intended to allow for differing visibility conditions and incursion scenario timings. If required, additional THLs may be positioned to accommodate multiple departure runway entrances. THLs illuminate red when there is an aircraft stopped on the runway in the takeoff hold position or commencing takeoff roll and the runway is unsafe for departure because it is currently occupied or about to be occupied by entering or crossing traffic; they are off otherwise. To avoid interference with daily ATC operations, the THLs are extinguished just before the blocking or crossing traffic clears the runway, when it is safe for the departure to commence, allowing controllers to use anticipated separation.

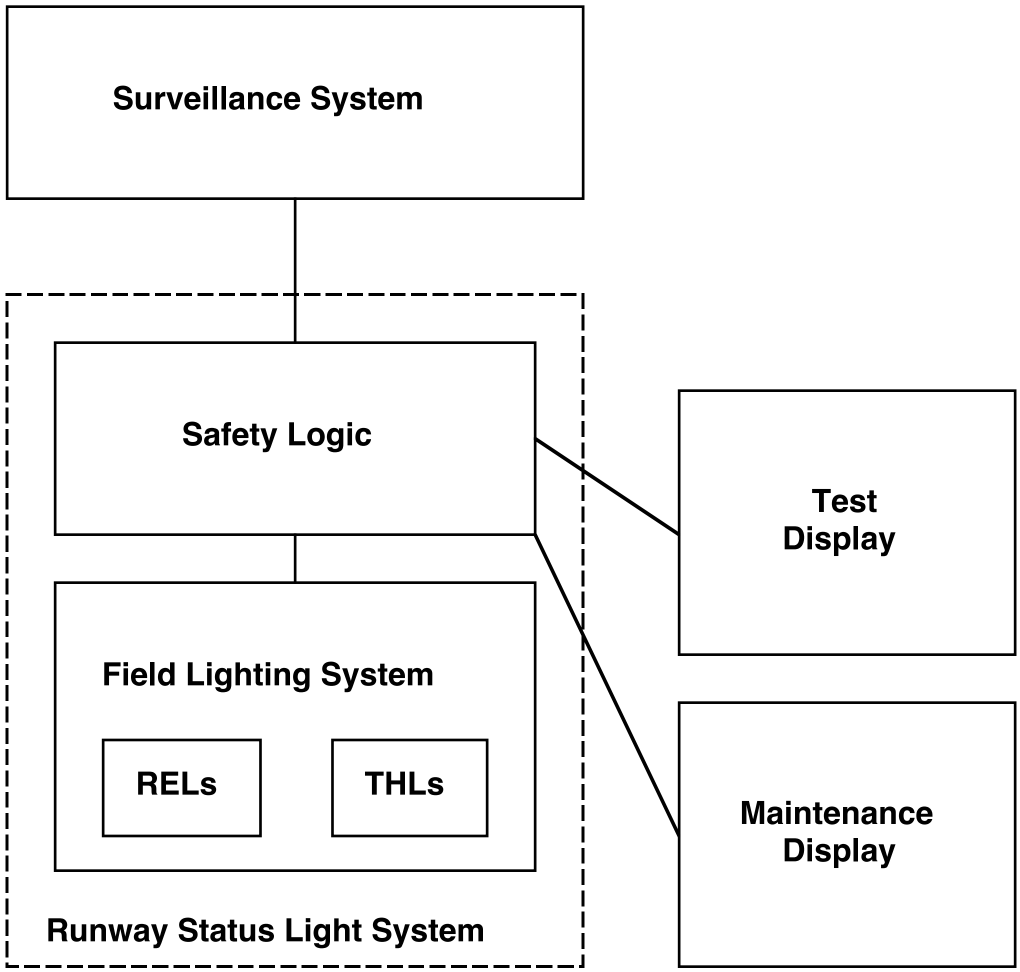

Figure 1. Runway Status Light System conceptual top-level diagram

In all cases, runway status lights indicate runway status only; they do not communicate a clearance. Clearance is provided by air traffic control (ATC) as under current local and national procedures, directives, and orders. A pilot or vehicle operator who sees a status light turn off must still obtain verbal clearance from ATC before proceeding. If clearance has been issued, but a status light is illuminated, the pilot or vehicle operator should stop and verify the clearance with ATC before proceeding. This will all be covered in the training material to all controllers, pilots, and vehicle operators.

Figure 1 shows a top-level conceptual diagram for RWSL. The system is driven by surveillance information obtained from an external surveillance system. The surveillance uses information from terminal radars, from a transponder multilateration system, and from a surface primary radar system to provide position and other information for all aircraft and transponder-equipped vehicles on and near the airport surface. Transponders must be on in the movement area for the multilateration system to provide reliable surface surveillance to RWSL. RWSL contains safety logic that processes the surveillance and commands the field lighting system to turn the runway-entrance and takeoff-hold lights on and off in accordance with the motion of the traffic.

THLs were not part of the initial DFW RWSL operational evaluation. Correct THL operation depends on surveillance based on a combination of beacon and primary radar returns. A feed from the current ASDE-3 was added to the formerly beacon-only DFW RWSL surveillance system, and sufficient operational experience was demonstrated with this testbed system to justify testing whether the RPMT system requirements for THL operation could be met.

3 Research Plan Outline

The RWSL is being developed by MIT Lincoln Laboratory under contract to the Federal Aviation Administration in order to assess its suitability in an operational environment. This assessment is planned to occur in three phases: engineering development, shadow operations, and operational evaluation. Each phase has a defined system implementation, test procedures, technical goals, and entrance and exit criteria. The phases are described briefly in this section.

3.1 Engineering Development

In the engineering development phase, the core functionality of the system was developed, tested, and demonstrated in a laboratory environment. Surveillance data were recorded at a field site to provide realistic inputs to the laboratory system. Software was written to read the recorded data, to process the surveillance information, to identify the operational state of each aircraft or vehicle on or near the runways, to project the range of expected behavior of the aircraft or vehicles, to determine which runway status lights should be illuminated, and to drive a laboratory display of the airport surface traffic and runway status light states.

The engineering development test is described separately in the engineering development test plan. [10]

3.2 Shadow Operations

The shadow operations phase emphasized real-time but non-operational use of the RWSL safety logic and displays in the field environment. Live surveillance data were introduced to the RWSL safety logic software to drive displays showing the airport traffic motion and status light operation in real time. The actual lights were not active, however, and no interaction with operational controllers, pilots, or vehicle operators occurred. Instead, the system was shown in a non-operational environment to air traffic personnel and pilots to elicit their assessment of the operational concept and suitability. The THL shadow operations test were conducted during the REL extended operational evaluation, so RELs were active on the field, but the THLs were not. Feedback and quantitative assessment from this phase allowed fine-tuning of the system dynamics in preparation for the operational evaluation phase.

The shadow operations phase is described in greater detail in the shadow operations test plan. [11]

3.3 Operational Evaluation

The operational evaluation phase will test the operational suitability of the runway status light system. A field lighting system will be installed on the airport. The lighting system will be tested prior to operational evaluation. Pilots and vehicle operators will view lights, which will be driven dynamically by the RWSL safety logic software in response to live surveillance. A manual shutoff switch will be available in the tower to disable the system. Air traffic personnel, pilot, and vehicle operator feedback will be elicited to support determination of the operational suitability of the RWSL system at DFW. Technical performance data will be collected and summary performance statistics will be generated by automated test software.

The operational evaluation is described in detail in the following sections.

4 Performance Measures

Two classes of performance measures were collected during the operational evaluation: operational feedback and technical performance.

Operational feedback was the primary focus during the operational evaluation. This information consists of comments, notes, and observations, as well as responses to questionnaires from pilots. The operational feedback determines when and to what extent RWSL affects the normal operation of the airport.

Technical performance data were used to monitor system technical performance and to provide a context for the operational feedback. The technical performance metrics for the operational evaluation are defined in the engineering development test plan.

5 Operational Evaluation Roles and Responsibilities

5.1 FAA ATO

The sponsor of the RWSL program and the operational evaluation was FAA ATO. The sponsor was responsible for all program management functions including tasking and directing the team members in the conduct of the operational evaluation and hosting meetings of the RPMT.

5.2 MIT Lincoln Laboratory Team

The MIT Lincoln Laboratory operational evaluation team included the technical lead of the project, the human factors specialists, the software developers, and the analysts. This team had prime responsibility for insuring a successful operational evaluation. Members of this team worked closely with DFW personnel for the duration of operational evaluation to maintain the system and to collect and record the data. This team interacted with the Field Lighting System (FLS) team and surveillance system vendors as necessary. The MIT Lincoln Laboratory resident DFW site coordinator assigned specifically to support the RWSL program served as the DFW point of contact for the operational evaluation at DFW. The MIT Lincoln Laboratory site coordinator interacted with the airlines and airport manager to schedule training of airline pilots and vehicle operators. The site coordinator also coordinated with pilots, vehicle operators, and controllers to set up methods for obtaining operational feedback.

5.3 FAA DFW Team

An ATC supervisor team was established, and consisted of eight (8) DFW tower supervisors. The team members kept their membership and participation in the RWSL program throughout the evaluation phases at DFW from local optimization, through shadow operations, and to the conduct, completion, review, and reporting of operational evaluation activities and results. The team underwent appropriate training and assisted in tuning the runway status light system before the formal operational evaluation began.

The team performed as subject matter experts during the operational evaluation. They were interviewed verbally.

DFW Airway Facilities supported the installation and maintenance of any RWSL hardware or cabling by providing access to the equipment rooms and ensuring the RWSL work did not interfere with operational systems.

5.4 Pilots and Airlines, including pilots' unions

All pilots who fly in or out of DFW during the RWSL operational evaluation had access to RWSL training material. Through coordination with the RWSL team, the airlines trained their pilots and motivated them to assist in the evaluation by submitting questionnaire responses, in written form or online, in a timely fashion during the operational evaluation. Pilots not flying for an airline were also asked to submit questionnaire responses. Pilots were also verbally interviewed. The questionnaires and interview questions were given to the pilots' unions for their information prior to the operational evaluation. Pilots were requested to leave aircraft transponders on while in the movement area.

5.5 Vehicle Operators

All vehicle operators approved to operate in the runway environment underwent RWSL training for REL usage. No training was required for vehicle operators for THLs. The DFW airport administration office managed the training of vehicle operators. Some airport vehicles were equipped with transponders and the drivers instructed by the DFW airport administration office to leave the transponders on during the daily testing periods in order to assist with completeness of multilateration system data.

5.6 DFW Airport Authority

The DFW Airport Authority coordinated RWSL training for approved vehicle operators.

5.7 Research Project Management Team

The Research Project Management Team (RPMT) had authority for determining the advancement of the program from phase to phase as outlined in Section 3. Representatives from the RPMT were invited to observe the operational evaluation test. The RPMT was briefed with the results of the test. The RPMT is responsible for assuring the confidentiality of all recorded information. At the conclusion of the operational evaluation, the RPMT will review all available data and will provide an assessment of the operational suitability of RWSL for FAA management review and approval.

5.8 FAA Technical Center

The FAA William J. Hughes Technical Center (WJHTC) will assist in the development of the test methodology and in the training and data collection activities during the operational evaluation at DFW. They will work in collaboration with the MIT Lincoln Laboratory test team of human factors experts and safety logic experts. They will provide an independent assessment and oversight of the test.

5.9 FAA Flight Standards

FAA Flight Standards was responsible for determining the acceptability and suitability of airfield light placement, light configuration, and the effect of such lights on pilots. They interacted with FAA ATO and MIT Lincoln Laboratory.

5.10 Field Lighting System Vendor

Siemens Airfield Solutions, the Field Lighting System (FLS) vendor, configured and performed initial tests on the FLS. The FLS interface with the RWSL system followed an interface specification given in the RWSL FLS RFP [1].

5.11 Surveillance Vendors

Sensis Corporation has built, installed, and adapted a portion of its ASDE-X system for DFW. Sensis was responsible for any re-engineering required for the ASDE-X equipment.

Primagraphics Ltd. has built and adapted its CAT Track radar plot extraction and tracking system for the west DFW ASDE-3.

6 System Components

RWSL system components were located on the airfield, in the southwest lighting vault, and in the west and center towers. The system used surveillance inputs covering the west side of the airport and approach areas.

6.1 Airfield Components

The RWSL Field Lighting System (FLS) includes RELs and THLs and their associated individual light controllers, installed in designated taxiways along and takeoff positions on runway 18L/36R (as shown in Figure 2). The lights and controllers are installed in fixture bases that also contain the isolation transformers to connect to the dedicated RWSL airfield lighting cable.

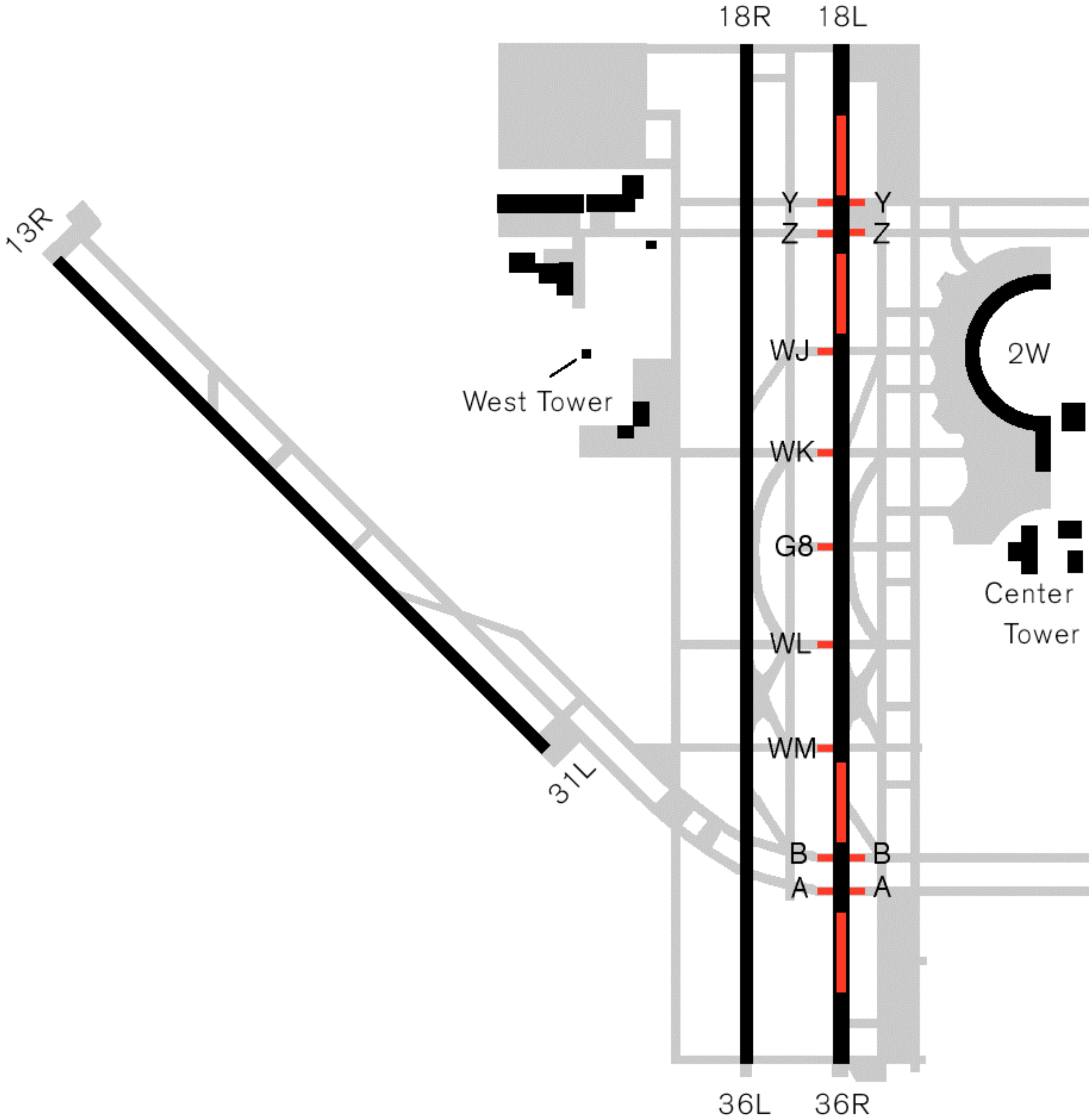

Figure 2. Adaptation for operational evaluation on DFW runway 18L/36R. RELs and THLs at equipped locations are shown here in red.

6.2 Southwest Vault Components

The Airfield Lighting Equipment installed in the southwest vault includes two (2) master cable controllers, two (2) constant-current regulators, the field lighting computer, the manual shutoff relays (that turn the regulators on or off), and the associated RWSL fiber optic interface devices.

6.3 West Tower Components

The RWSL equipment temporarily installed in the DFW west tower required for the operational evaluation included one (1) test administrator computer, one (1) Ethernet switch, and one (1) manual shutoff switch with cover.

6.3.1 RWSL Test Administrator Computer

The RWSL test administrator computer provided lighting control via a graphical user interface. It was installed temporarily in the tower cab. Lighting control allows selection of runway configuration for north or south flow, a soft-off button, selection of operational mode for normal or heavy rain conditions, and setting the light intensity to one of five levels. The computer provided a display of the selected settings, as shown in Figure 3. The computer also provided a Traffic and Status Display that shows the states of the runway-status lights, runway and taxiway outlines, and the traffic in plan view, as shown in Figure 4. Aircraft and surface vehicles are shown as icons. The data tags show in the first line the flight ID and heavy indicator if available, otherwise a tail number if available. The data tags show in the second line the fix pair (DFW for arrivals, first fix for departures) if available, and the equipment type if available timeshared with the speed in knots. Aircraft on final approach are depicted on an approach bar near the arrival end of the runway. The approach bar represents five nautical miles of approach space. The displays may be zoomed, panned, rotated, or recolored as needed to optimize usability. Multiple windowing capability is also available for expanded or displaced views of interesting areas.

Software adaptation limited the Traffic and Status Display presentations to represent the actual operational evaluation deployment of RWSL on 18L/36R (as shown in Figure 2) for the purpose of depicting the light states and the field lighting control status. The computer and display are shown in Figure 5.

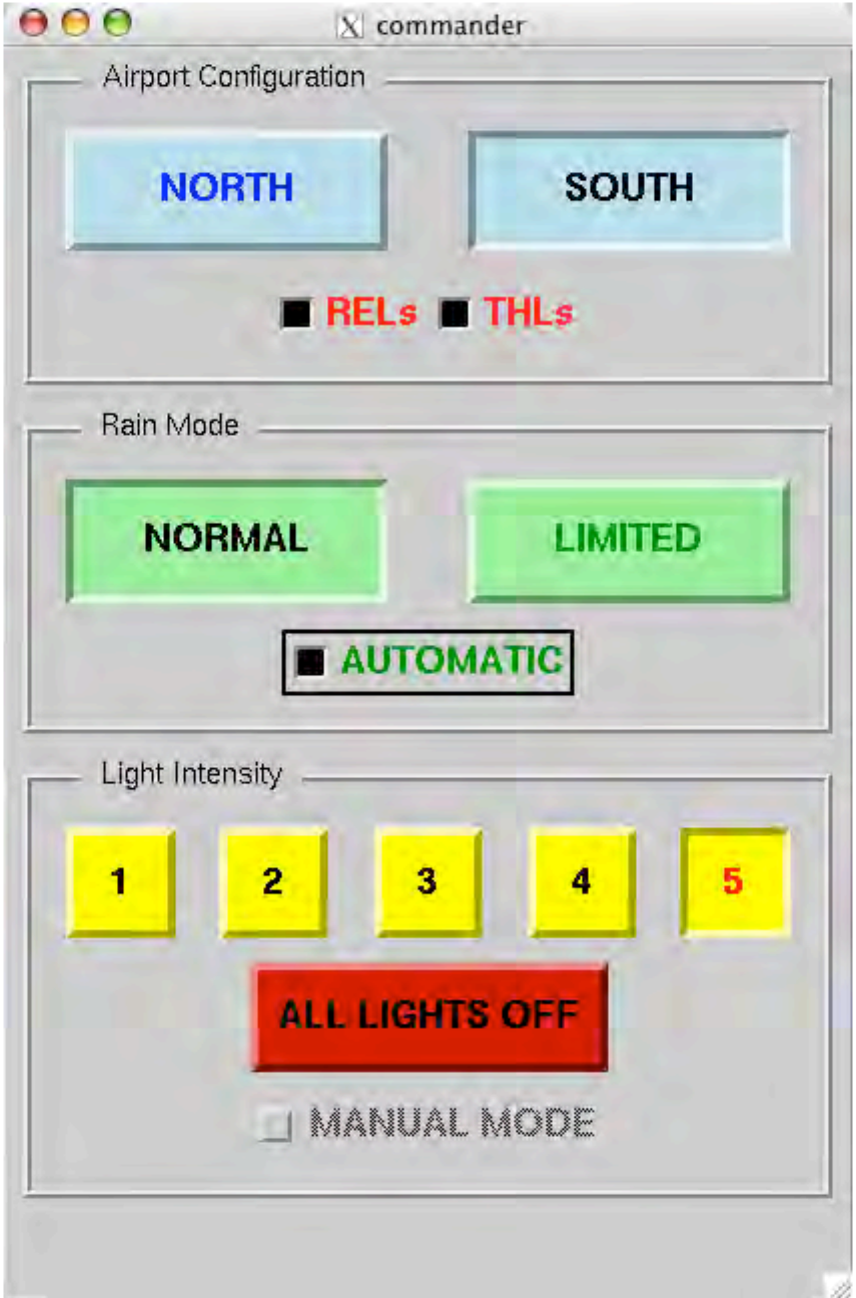

Figure 3. RWSL lighting control display

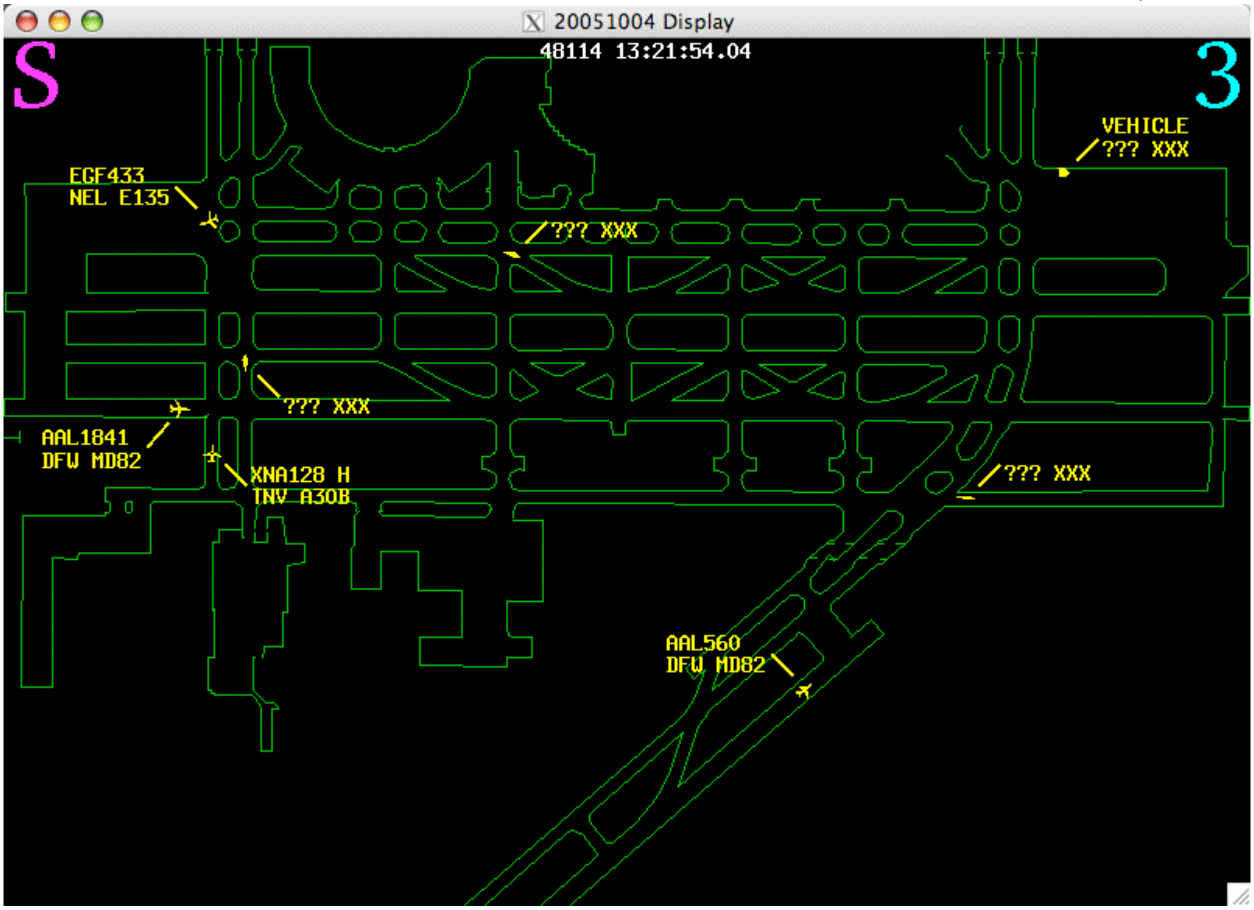

Figure 4. RWSL traffic and status display

Figure 5. Test administrator computer for temporary installation in the tower cab

6.3.2 Manual Shutoff Switch

The manual shutoff switch remotely controlled the on/off state of the constant-current regulators (by activating co-located relays) in the southwest lighting vault, via a dedicated communications circuit that bypasses all other airport and RWSL equipment. The manual shutoff switch with cover is shown in Figure 6. The manual shutoff switch was already installed and no change was necessary for this test.

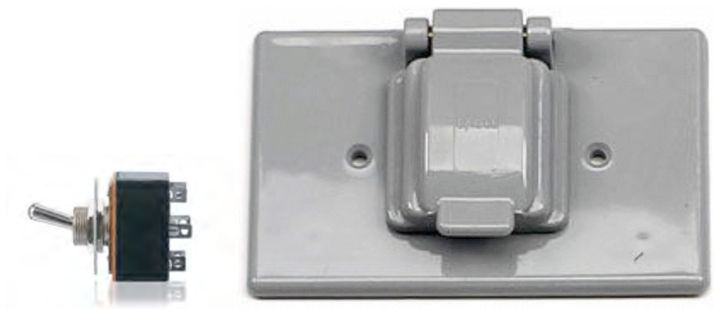

Figure 6. Manual shutoff switch and cover.

6.4 Center Tower Equipment

The RWSL hardware used during REL operational evaluation tests was maintained for use during THL operational evaluation. It includes:

- One (1) Sun Fire server (rack mount)
- One (1) Sun Blade 2000 computer (tower configuration)
- Two (2) General Digital Genstar 20" flat panel monitors
- One (1) network switch
- Two (2) pairs of Raritan Cat5 Reach KVM extenders
- One (1) tape drive
- Two (2) keyboard/mouse sets
- One (1) Sony AIR-8 receiver
- One (1) AOR AR-3000A receiver (see Figure 10)
- One (1) Comtrol DeviceMaster RTS device server (see Figure 7)
- One (1) Omnitron FlexPoint 100Fx/Tx ethernet-to-fiber media converter (see Figure 8)

During operational evaluation, one of the 20" flat panel monitors remained in its position mounted on a Strongarm mount (see Figure 9) in the center tower cab. This allowed a Traffic and Status Display Unit to be available for educational use in the center tower. This display unit will be removed or stowed if required.

Figure 7. Comtrol DeviceMaster RTS device server.

Figure 8. Omnitron FlexPoint 100Fx/Tx ethernet-to-fiber media converter

Figure 9. Strongarm monitor arm.

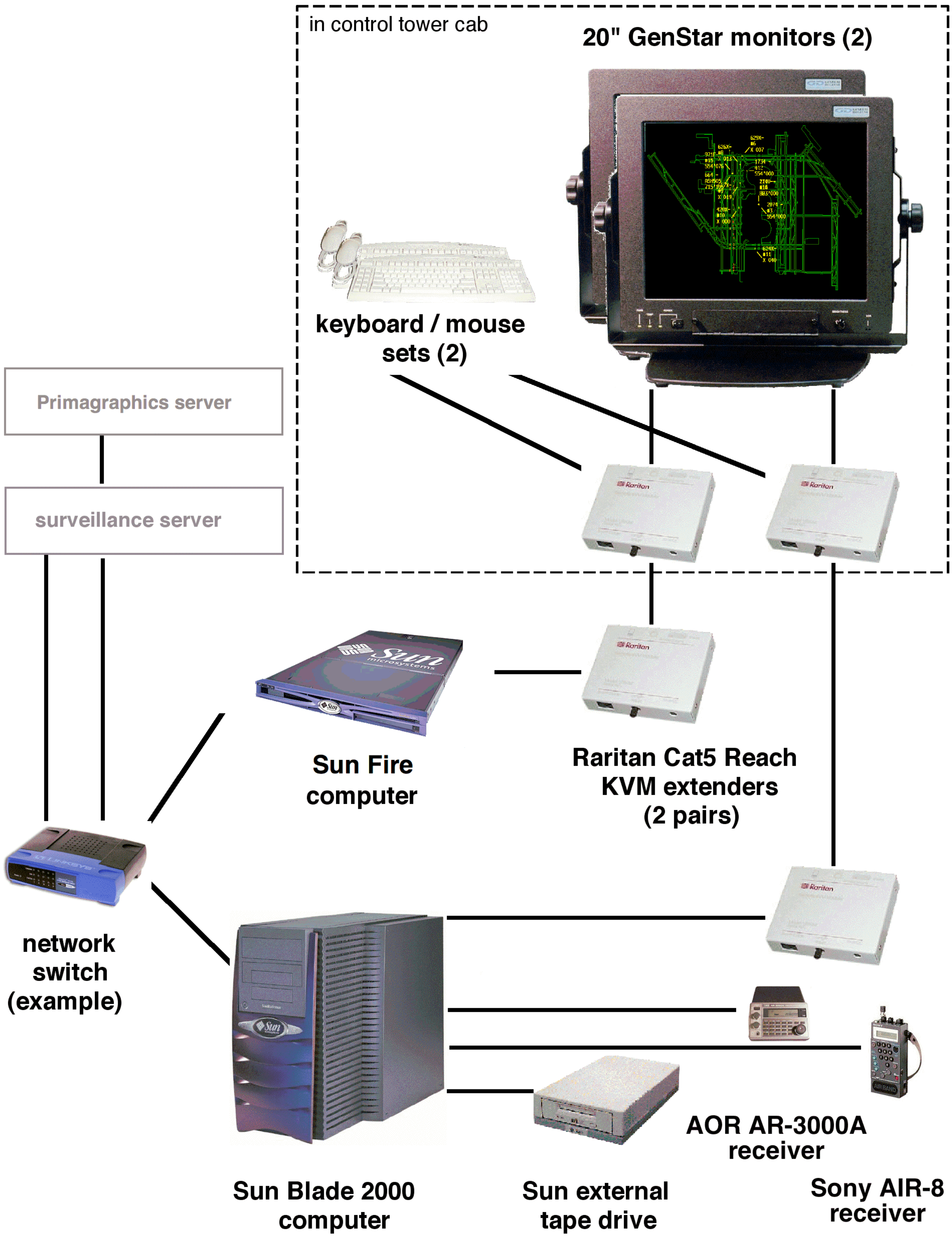

Figure 10. Hardware installed at the DFW Center Tower for THL operational evaluation.

6.5 Deinstallation

The RWSL hardware installed in the DFW West and Center Towers for operational evaluation were removed or stowed in non-interfering locations when not in use. The keyboards and displays were able to be positioned out of the way, or removed easily within 30 minutes. At the end of the operational evaluation tests, all installed hardware was scheduled to be removed entirely when directed by the FAA and the DFW airport authority.

7 Training

A successful evaluation will depend on the thorough training, knowledge, and commitment of three categories of users: controllers, pilots and vehicle operators. The following sections provide an overview of the required training. In order to accomplish the required training, MIT/LL employed a "train the trainer" concept. The MIT/LL team worked with the FAA to develop training materials to support the outcomes outlined for the three categories of users described above. FAA personnel received training that met the requirements of DFW Air Traffic management.

7.1 West Tower Training

Operational controllers in the west tower had a passive role in the evaluation. When the RWSL system operated in accordance with its design requirements, the RWSL operations from the tower proved to be seamless with no noticeable effects unless a potential incident occurred. Notwithstanding this passive role, controllers were familiar with the operational concept. They were also prepared to respond to the possibility of pilots questioning clearances when RWSL indicates an unsafe condition, as well as when the system appears to deviate from normal operation.

Air traffic controller supervisors and controllers-in-charge were trained to make the necessary keyboard or trackpad entries on the RWSL lighting control remote display to accommodate changes in operational mode, traffic flow, rain condition, and light intensities. They were also trained to disable the RWSL system by going to an off configuration (soft kill), disabling the RELs or THLs separately, or by shutting off the current to the light fixtures (hard kill). In the event that a controller supervisor, controller-in-charge, or test administrator is not present or available during any portion of the RWSL evaluation, the RWSL was disabled and the ATIS updated to reflect this situation.

7.2 Pilot/Operator Training

Pilots and vehicle operators were required to have an awareness of the operational concept. All participating pilots needed to understand that a red illuminated light indicates that the runway is unsafe for entry or crossing at that location or for departure from that location. They needed to understand that RWSL information does not constitute a clearance; specifically that the absence of a red illuminated light does not indicate permission to proceed. They needed to be alert to the fact that during the operational evaluation not all intersections will have runway status lights, not all takeoff positions will have THLs, and the system may not always be operational.

In general, pilots received their training through company channels. This was supplemented by various means including an Internet website, articles in various pilot and aviation magazines, presentations at pilot and industry conferences, NOTAMs, ATIS broadcasts, Jeppesen inserts, pilot bulletins, a letter to airmen, CD-ROMs, posters, and scripted animations and recorded data movies. Materials were delivered to over 70 contacts in all. American and Eagle managers and FAA pilots were briefed at their safety meeting. One airline (AAL) added RWSL to their recurrent training for all DFW pilots. Lincoln also coordinated with airline pilots unions throughout the operational evaluation.

Vehicle operators received their training in accordance with standard airport operations practices.

7.3 Training Methodology

In order to accomplish this operational evaluation, MIT/LL will employ a “train the trainer” concept. The MIT/LL team will work with the FAA to develop training materials to support the outcomes outlined for the categories of users described above. FAA personnel will receive training that meets the requirements of DFW Air Traffic management.

8 Pre-test Activities

8.1 Local Optimization

Prior to the operational evaluation, Lincoln with the support of the controller supervisor team fine-tuned the optimization of the system at DFW. This allowed the system to be tuned on an intersection-by-intersection basis to accommodate local operational procedures, including the use of anticipated separation, by minimizing interference. In particular, it allowed retuning the system to account for any delays incurred by the field lighting system and to accommodate changes made after shadow operations tests.

Lincoln, with the support of the controller supervisor team, identified anomalies at each takeoff-hold position via the RWSL test display located in the center tower, in conjunction with viewing the actual traffic from the tower cab. They conveyed to the MIT/LL personnel the nature of the adjustment needed to minimize interference at each location, and evaluated the adequacy of the adjustment made, as reflected in subsequent instances of interference at each location (i.e., the need for additional adjustment, if any). Recorded scenarios were also used as needed for optimization.

8.2 FLS Integration and Phased Turn-On

A series of tests was conducted to ensure that the FLS had been properly installed and configured, that RWSL-FLS communication continued to work, and that the FLS satisfied operational and performance requirements. Three integration test phases were completed: an FLS site acceptance test, an RWSL/FLS integration test, and a flight test. Detailed plans were given in the FLS acceptance and integration test plan [12] and the flight test plan [13].

Three rounds of flight tests were performed: 3–4 December 2005, 21–22 December 2005, and 28 January 2006. During the initial tests, the THL lamps were deemed insufficiently visible, and were upgraded. In addition, the RWSL surveillance processing software was augmented to improve false track rejection.

8.3 Test Readiness Review

A test readiness review was conducted after the local optimization and integration and prior to commencement of operational evaluation. This review verified that the system was ready for test. The RPMT and all interested parties was invited to participate in the test readiness review. A detailed test readiness review checklist was prepared for review by interested parties. The test readiness review was completed on 14 February 2006.

9 Test Activities

9.1 Technical Support

The RWSL test team ensured that the RWSL hardware was in its test configuration, was operating correctly, and was ready for testing. The RWSL test team also verified that any ancillary equipment such as radio receivers was properly configured. The RWSL test team ensured that the recorded data was archived for analysis.

Basic system operation required that a RWSL test team member log in with a password, enter a script command to start the system, run the test, enter a script command to stop the system, and log out. This can be done locally or remotely from the MIT/LL site. A script was installed that performed this activity automatically at midnight local time.

In addition to basic system operation, the RWSL test team members were also responsible for entering time-stamped log and commentary data during the test sessions, periodically backing up technical performance data to removable media, and shipping the data back to Lincoln Laboratory for analysis. Much of this activity was also performed automatically by a script.

9.2 Test Administrator

The test administrator entered the operational mode, runway configuration, rain condition, and light intensity into the RWSL lighting control display as needed when conditions changed during the course of operational evaluation. The test administrator was assigned by MIT/LL on a daily basis.

9.3 Air Traffic Controller Supervisor Participation

The supervisor coordinated the entry of RWSL status into the ATIS message. The tower supervisor also acted as liaison between the test team and tower personnel. After an initial period, the supervisors took on the role of test administrator.

9.4 Pilot participation

Since the runway status lights were shown on a continuing basis during the operational evaluation test periods, a large representation of pilots who frequent DFW participated in the evaluation. Pilots were asked, through their airline company office or through the FBO, to provide responses to a questionnaire, available either in written form or online on the RWSL website.

9.5 Other observer participation

In addition to the active participants, a cross-section of interested parties and stakeholders were invited to the operational evaluation. Such groups included FAA headquarters and regional office management, DFW airport management, airline representatives, and pilot union representatives. They were most readily accommodated as observers in the center tower, but after prior coordination with the DFW facility manager some were admitted to the west tower for observation.

9.6 Test Duration

The operational evaluation was six months in initial duration and was extended to allow continued testing. THL operation was intended to operate initially on a part-time basis, but in fact always operated on a full-time basis, limited to those times when a supervisor was on duty and RWSL was in service.

10 Data Collection

The operational evaluation provided three different categories of data, each with its own data collection method. Technical data were recorded automatically during test periods for later offline analysis. Operational feedback was elicited from pilots for subsequent evaluation. Audio recordings of operational control frequencies were obtained for selected time periods. Access to recordings was limited to select FAA and test team personnel. Recordings were not released to any other individual or organization without the express consent of the RPMT. Analysis and assessment methods will be described in the following section.

10.1 Technical Data

All RWSL system input and output data were recorded during tests. These data include surveillance system inputs to RWSL and light commands produced by RWSL. Safety logic internal data were also recorded to facilitate subsequent technical performance analysis. All data were time-tagged to allow replaying and post-processing the data for analysis. In addition, a time-tagged text logging facility was used to annotate the tests. This was used to record wind and weather information, operational and technical observations, and any other text-based information as needed. All adaptation data used in the test were recorded with the test data for configuration control.

10.2 Operational Feedback

The operational feedback resulting from the conduct of the operational evaluation included initial feedback relating to workload and situational awareness issues. Elicited observer feedback included suggestions for system tuning and safety enhancement. With respect to instances of interference, the participating members of the supervisor team evaluated performance and assessed operational suitability (see Section 11.3.3). Separate timing tests were also performed.

10.3 Voice Recording

Voice transmissions between air traffic controllers and pilots and vehicle operators were recorded for confidential unofficial post hoc analysis. The recordings will be destroyed on direction from the FAA. Recorded data shall not be used to implicate a controller, pilot, or vehicle operator in a safety violation or incident.

11 Technical Data Analysis

11.1 Operational Environment

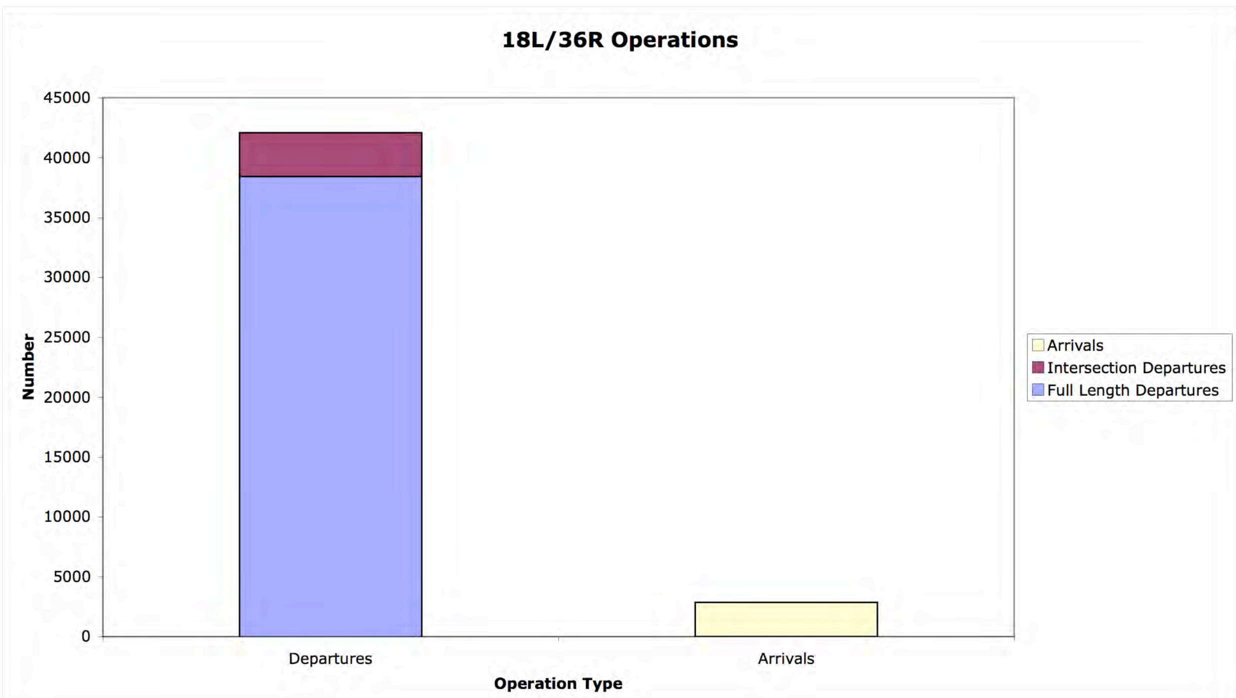

Figure 11. 18L/36R operations.

This report includes an assessment of the operational data for the period 24 February – 26 July 2006, including 101 days of operation, 5 of which were partial days. This provided 2347 hours of system operation, defined as THL lights enabled at non-zero power level. During this period, there were 44,943 operations on 18L/36R. About 94% of the operations (42,083) were departures, 91% of which (38,418) were full-length departures and 9% of which (3665)were intersection departures. There were 2860 arrivals.

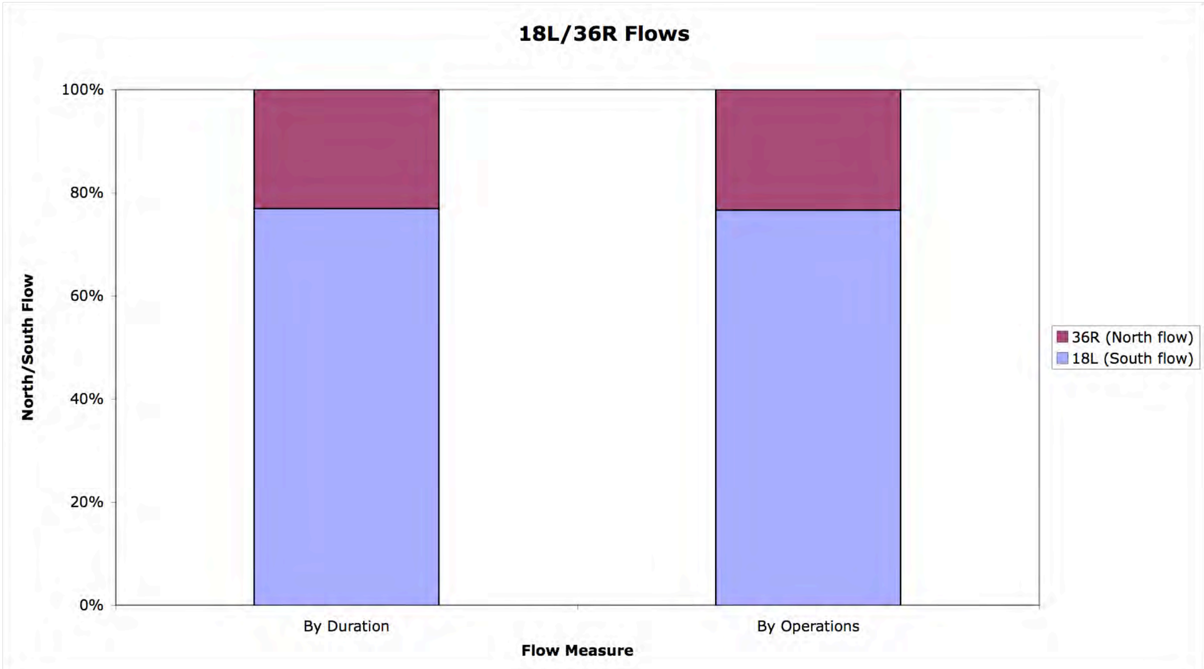

Figure 12. Runway configuration according to duration or number of operations.

About 75% of the operational evaluation was in south flow (runway 18L). This was true when measured by duration or by number of operations. The remaining 25% was in north flow (runway 36R).

11.2 Technical System Operation

11.2.1 Lighting System Utilization

During the operational evaluation, 33% of the departures (14,036) were affected departures, that is, exposed to illuminated THLs. There were in total 18,010 THL illuminations, or about 1.28 per affected departure. This is because an aircraft in position for departure may be exposed to more than one illumination due to multiple runway crossings in front of it.

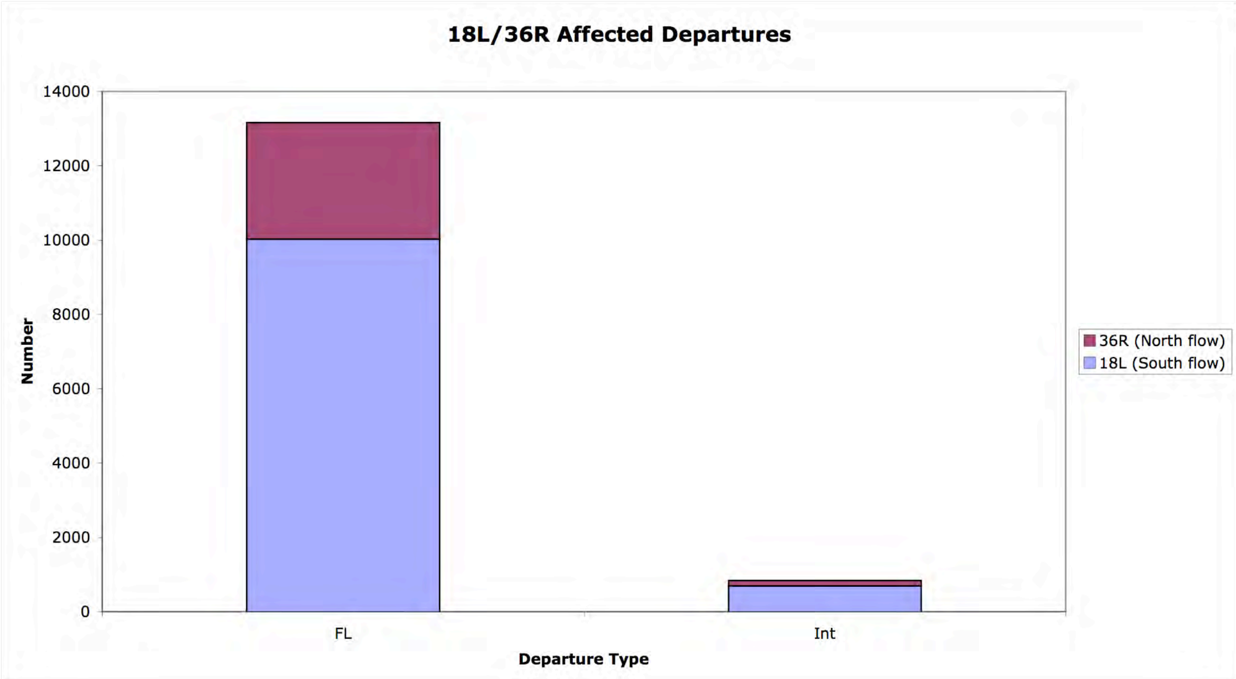

Figure 13. Affected departures according to departure location.

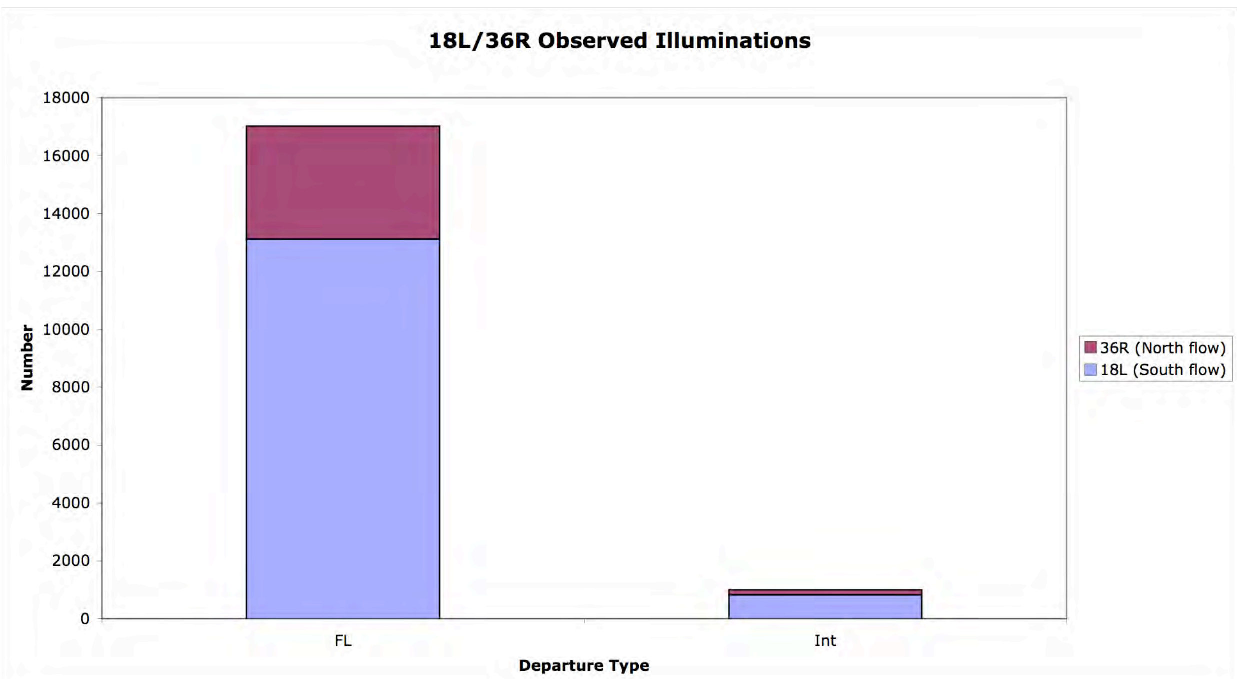

Figure 14. Observed illuminations according to departure location.

11.2.2 Lighting System Intensity Usage

During the operational evaluation, the light current level was controlled automatically according to an agreed schedule. The system changed the light current level to level 5 (the brightest setting) 15 minutes before sunrise and to level 3 (medium) 15 minutes after sunset. Sunrise and sunset times were calculated for each day algorithmically.

11.3 Light System Performance

The purpose of the light system performance was to assess the correctness of light operation. Three metrics were used: missed detections (MDs), false activations (FAs), and instances of interference (I).

11.3.1 Missed Detections and False Activations

A two-step process was used to produce the missed detection and false activation metrics. First, performance analysis software was run using the recorded data and adaptation data as inputs. The result of the performance analysis software was a set of tables with precise information about each arrival and departure and the timing performance of the runway-entrance and takeoff-hold light commands issued by the RWSL safety logic. Preliminary identification of anomalies (missed detection and false activation events) was performed automatically by the performance analysis software. The information logged with these anomaly candidates includes automatic determination of whether the anomaly could have been observed by a pilot or vehicle operator, the track(s) involved in the anomaly, and the anomaly type, location, and timing. Additional events identified by the supervisor team were also logged and included in the analysis.

The second step was to review the output of the performance analysis software manually. Events of interest were replayed and the display used to assess the candidate anomalies to verify the automatic assessment output. Anomalies were grouped into causally related events. The numbers of verified anomaly events of each type were tallied and normalized as specified in the engineering development phase plan. The results for THLs are reported here.

11.3.2 Instances of Interference

An interruption of normal, safe, controlled, operations caused by the status lights is known as interference. For example, a pilot may hesitate to accept a clearance or actually call the controller to question a clearance that is not consistent with an illuminated light even though the clearance is correct and the resulting action would be safe. Interference therefore has the potential to cause delays, added workload to both the pilot and controller and consequential disruption to air traffic control of the runway environment. Unlike missed detections and false activations, this metric cannot be fully determined by analysis of recorded RWSL data. Cases of interference must be identified by experienced end-users. Supervisor test participants reported the cases of interference they observed, and the tally of these numbers was added to any additional cases of interference counted by the automated analysis for a total count of the interference metric.

11.3.3 Anomaly Causes

The identified anomaly causes were placed into one of the following nine categories:

11.3.3.1 ASDE-3 maintenance in normal mode

When the ASDE-3 is undergoing maintenance, typically the behavior of the tracks produced by the Primagraphics radar tracker used by RWSL is a total cessation of track data of variable duration, followed by a period lasting less than a minute with large numbers of false tracks; normal tracking ensues thereafter. The RWSL system is designed and adapted to detect this behavior and to ignore ASDE-3/ Primagraphics data during the maintenance period. RWSL can be set manually to override ASDE-3 maintenance detection. The manual override can be set and forgotten, which makes it quite possible for the override to persist until the next period of ASDE-3 maintenance, whereupon a large number of false tracks can be submitted to the RWSL safety logic, resulting in false activations or interference.

Resolving this problem will require a modification to the mode determination logic to put a time limit on manual override of ASDE-3 maintenance detection. This modification has been prepared and will be in the next RWSL software release.

11.3.3.2 ASDE-X false track

The prototype ASDE-X at DFW can produce false tracks. These are typically aircraft parked in the gate area, whose transponder emissions are subject to a severe multipath environment. If the ASDE-X multilateration is corrupted by the multipath, a false track, corresponding to a false position of a real aircraft, is produced. By far most of these false tracks are stationary or slowly moving, but if they happen to occur on the active runway, they can erroneously cause activation of the THLs.

This problem caused THL FAs on 14, 17, and 19 March 2006, resulting in RWSL and ASDE-X being taken offline for maintenance. The ASDE-X was returned to service on 24 March 2006 with its false target algorithms tuned more appropriately for the DFW environment. RWSL RELs were enabled shortly thereafter, but the false track rate was still sufficiently high to disallow THL operation at that time. New ASDE-X false track rejection algorithms were designed and implemented by Lincoln Laboratory to eliminate the remaining ASDE-X false tracks and were tuned with DFW ASDE-X data. RWSL THLs were returned to service on 4 May 2006. No THL anomalies were caused ASDE-X false tracks after that date.

11.3.3.3 ASDE-X split track

The ASDE-X sometimes produces two tracks for the same aircraft. Commonly one is based on Mode S (squitter) transmissions and the other on Mode A (4096 code) or Mode C (altitude) transmissions, but this is not always the case. Often when there are two tracks, one of them behaves poorly: it has a low or inconsistent update rate, or the surveillance is not as accurate. It is possible that the split track could interfere with the Lincoln fusion algorithm if there is an ASDE-3/Primagraphics track, but this was not a significant problem. Usually a split track causes

THL anomalies only if one of the tracks has large track gaps. In this case a split track can produce FAs due to one track being in the arming region and the other in the activation region.

This problem was largely resolved by designing and implementing a split track correction algorithm.

11.3.3.4 ASDE-X track gap

The ASDE-X occasionally has multilateration tracks with poor probability of detection. This results in a gap in the surveillance for an aircraft, which can cause a THL MD. It is also possible that a track gap will cause a FA because the lack of track updates keeps a light on too long. A FA due to an ASDE-X track gap was not seen during the operational evaluation, however.

Resolving this problem will require an upgrade to the ASDE-X.

11.3.3.5 Operational incompatibility

One case of operational incompatibility was noted during the operational evaluation. An MD-82 was crossing 36R at WK, but could not complete its crossing due to traffic in front of it. Its multilateration position was clear of the runway, but the aircraft tail was not. A second MD-82 was in position for departure, and so operationally the THLs should have been illuminated, but were not, forming an MD.

Resolving this problem will require RWSL to be upgraded to include aircraft extent in all the safety logic algorithms.

11.3.3.6 Rain in normal mode

In periods of heavy rain, the ASDE-3 output becomes cluttered with returns from the rain itself. The behavior of the tracks produced by the Primagraphics radar tracker used by RWSL is a large number of false tracks during the rain, often localized to those regions receiving the heaviest precipitation; normal tracking ensues thereafter. The RWSL system is designed and adapted to detect this behavior and to ignore ASDE-3/ Primagraphics data during periods with large numbers of spurious tracks. RWSL can be set manually to override rain detection. The manual override can be set and forgotten, which makes it quite possible for the override to persist past the period required by the precipitation, whereupon valid surveillance is ignored, resulting in missed detections of aircraft whose transponder is turned off.

Resolving this problem will require a modification to the mode determination logic to put a time limit on manual override of rain detection. This modification has been prepared and will be in the next RWSL software release.

11.3.3.7 Safety logic bug

On 9 March 2006, a bug in the RWSL safety logic caused a THL to be persistently activated. This bug was triggered only if a truck drove through a narrow sliver of pavement just off runway 18L. Thereafter, any aircraft in position for takeoff armed the THLs, causing them to illuminate irrespective of the true state of the other traffic on the runway. This caused the controller supervisor to use the manual shutoff (hard kill) switch to disable RWSL.

The safety logic bug was identified and fixed, and the RWSL system was returned to service on 13 March 2006.

11.3.3.8 Taxi on runway

Aircraft taxi on the runway, typically when the airport is changing configurations or when the aircraft had taxied onto the runway for departure but was unable to execute the departure. If this occurs in an arming region while another aircraft is crossing the runway, then the THL will turn on in front of the aircraft in the arming region. As this illumination interferes with the taxi clearance, the anomaly may be considered as interference.

The taxi on runway problem could be addressed by redesign of the RWSL safety logic to incorporate a new state, Taxi On Runway (TOR). The purpose of the TOR state is to identify aircraft taxiing or vehicles driving on the runway with no intent to depart. RWSL would then not normally allow these aircraft or vehicles to enter the departure state. If RWSL also disables THL illumination in front of the aircraft taxiing on runway, the potential interference would be eliminated. The design of this state has been completed and its software implemented, but it has not yet been tested.

11.3.3.9 Transponder off in limited mode

An aircraft operating with its transponder off can only be seen by RWSL in primary radar surveillance from the ASDE-3/Primagraphics system. The problem could also be mimicked by a fault in the ASDE-X resulting in loss of track, and thus be equivalent to the ASDE-X no MLAT cause. In either case, no altitude information is available, and, for arrivals, no surveillance is available at all until the aircraft descends below about 200 ft AGL within the airport runway/taxiway environment. This can result in a missed detection in the THLs.

Resolving this problem will require better compliance with transponder operating procedures at DFW, or an upgrade to the ASDE-X if the problem is determined to have its origin there.

11.3.4 Anomaly counts

The anomalies were classified according to identified cause and by anomaly type. Table 1 shows all the THL anomalies by cause and type that were found during the operational evaluation. A total of 25 anomalies of all types were detected.

	Type			
Cause	**MD**	**FA**	**I**	**Total**
ASDE-3 maintenance in normal mode		1	3	4
ASDE-X false track		1	2	3
ASDE-X split track		2		2
ASDE-X track gap	1			1
Operational incompatibility	1			1
Rain in normal mode		5	3	8
Safety logic bug			1	1
Taxi on runway			1	1
Transponder off in limited mode	4			4
Grand Total	**6**	**9**	**10**	**25**

Table 1. Anomalies according to cause and type.

Not all of these anomalies were observed by aircraft or vehicles in a position to see the THLs on or off in error. The observed anomalies, numbering 23 in total, are shown in Table 2. The dominant causes of observed anomalies were sticky and fast ground bits and operational incompatibility.

	Type			
Cause	**MD**	**FA**	**I**	**Total**
ASDE-3 maintenance in normal mode		1	3	4
ASDE-X false track		1	2	3
ASDE-X split track		1		1
ASDE-X track gap	1			1
Operational incompatibility	1			1
Rain in normal mode		4	3	7
Safety logic bug			1	1
Taxi on runway			1	1
Transponder off in limited mode	4			4
Grand Total	**6**	**7**	**10**	**23**

Table 2. Observed anomalies according to cause and type.

None of the anomalies were observed by multiple aircraft. This is as expected, for a multiply-observed anomaly would require two aircraft in position for departure at the same time. Thus the anomaly observation counts are the same as the observed anomaly counts.

The anomaly, observed anomaly, and anomaly observation counts should properly be normalized to the number of operations that took place on runway 18L/36R during the good data periods. When the rates thus obtained are expressed as their inverses, they can easily be compared with the operational goals as expressed by the RPMT shown in Table 3:

Phase	MD	FA	I	Total
Engineering Development	320	1600	800	200
Shadow Operations	360	1800	900	225
Operational Evaluation	400	2000	1000	250

Table 3. Performance goals for the RWSL THLs, expressed as inverse anomaly rates (operations per anomaly).

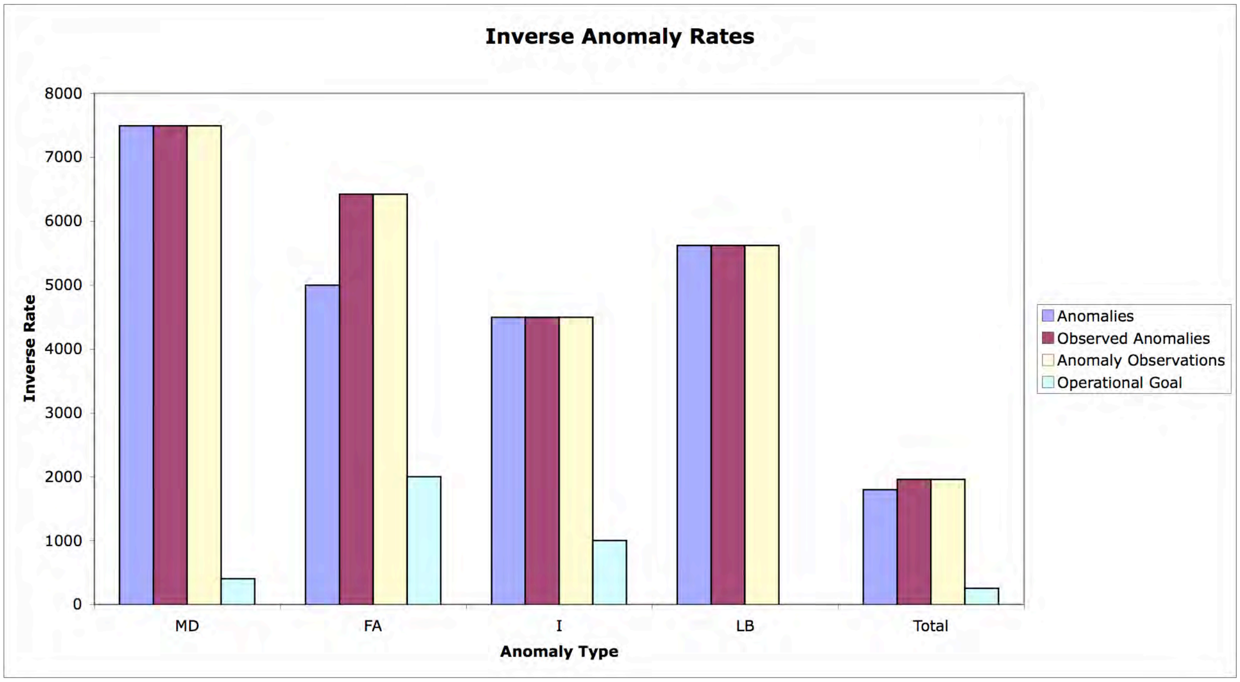

Figure 15. Inverse anomaly rates (larger is better).

The resulting comparisons are shown in Figure 15. The missed detection, false activation, and interference performance goals were uniformly exceeded by a good margin. In addition, if the RWSL system improvements put in place subsequent to the anomalies presented here are applied to the operational data for the anomaly events, most of these anomalies would not have occurred. The inverse anomaly rates would have been improved by a factor of eight over the actual rates shown here.

11.4 Light Busts

A light bust occurs when an aircraft or vehicle proceeds through an illuminated runway status light to cross the runway for runway entrance lights (RELs) or along the runway for takeoff hold lights (THLs). As such, a light bust is a severe type of interference. All eight light busts encountered during the THL operational evaluation are counted in the interference statistics presented above.

11.5 Controller-Pilot Communications Impact

During the operational evaluation period, all communication over the DFW West local and ground frequencies at 124.15 and 121.85 MHz, respectively, were recorded. Those periods during light system operation were made available for subsequent audition in order to log instances of communications concerning or caused by RWSL operation.

In view of previous operational experience for RELs at DFW, however, a detailed assessment of THL-induced controller-pilot communication was not undertaken. All anomalies (MD, FA, I) were listened to, however, as well as all near-anomalies identified by the automated assessment software. Only three cases of controller-pilot communications regarding THL operation were noted.

Although this was an incomplete assessment of the impact of THLs on communications, it is believed that THLs did not have a significant impact on controller-pilot communication during the assessed period. This assessment is supported by informal feedback from ATC.

12 Operational Feedback Analysis

12.1 Pilot Survey

The pilot survey comprised 18 yes/no response statements presented in a positive and negative counterbalanced order with additional comments encouraged. There were three survey methods: web site (at RWSL.net), telephone, and paper (placed near posters in Operations Centers). Most pilots used the website method to respond to the survey; the phone method was rarely used and is not included in this report because of insufficient response.

A total of 87 responses were received from pilots, 80 via the Web, 2 by telephone, and 5 in paper form. (The survey was the same except the data entry mode differed.) Surveys were collected over period of over three months from 24 February 2006 to 5 June 2006.

The overall reaction to the RWSL program and the THLs was very favorable among the participants.

12.1.1 Pilot Respondent Demographics

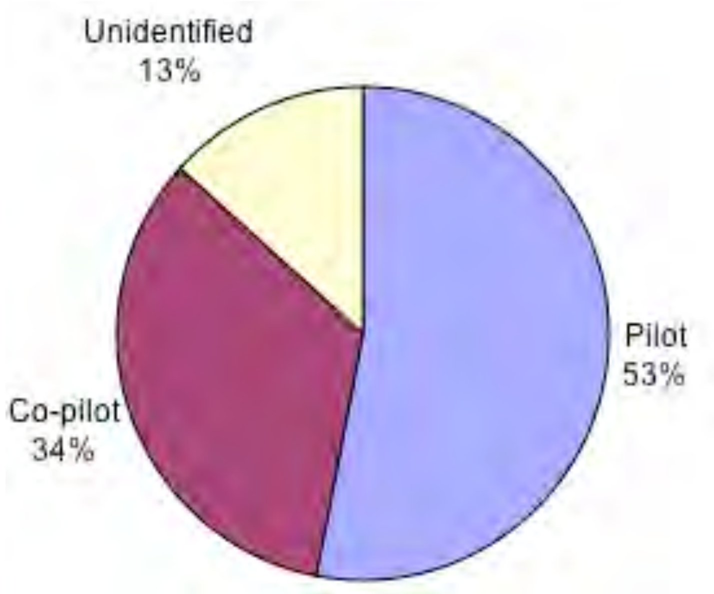

Figure 16. Respondent role.

Figures 16–19 describe the demographic characteristics of the respondents. About half the respondents were pilots, a further third were copilots, with the remainder having unidentified cockpit roles. About two fifths of the respondents had less than 10,000 flight hours, about one fifth had between 10,000 and 15,000 hours, and about a third had over 15,000 hours of flight experience.

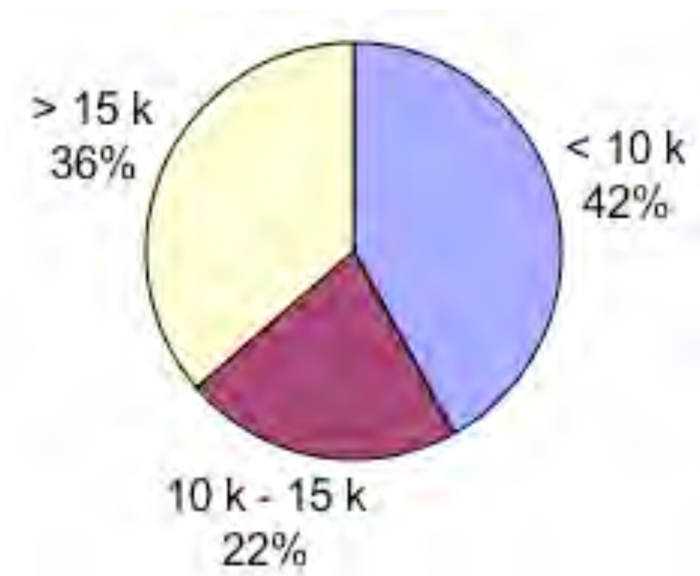

Figure 17. Respondent flight experience (hours).

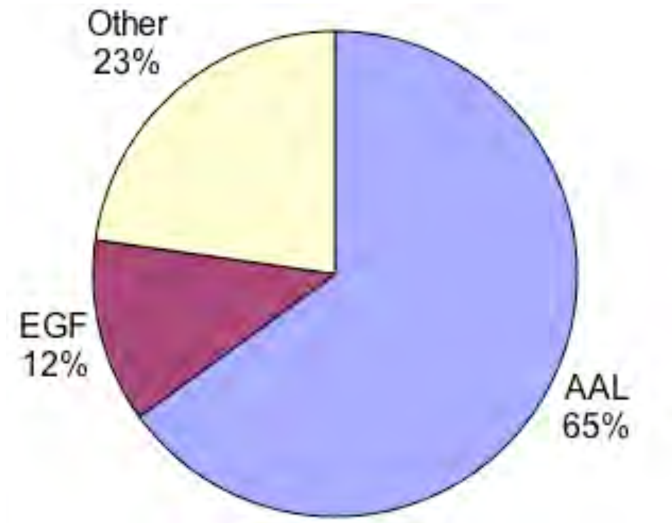

Figure 18. Respondent airline affiliation.

About two thirds of the respondents flew for American Airlines, about one eight for American Eagle, and the remaining for a variety of other airlines or in general aviation. One eighth of the respondents replied to the survey before they had seen THLs in operation, about half had seen THLs operate between one and five times, and two fifths had seen THLs operate more than five times.

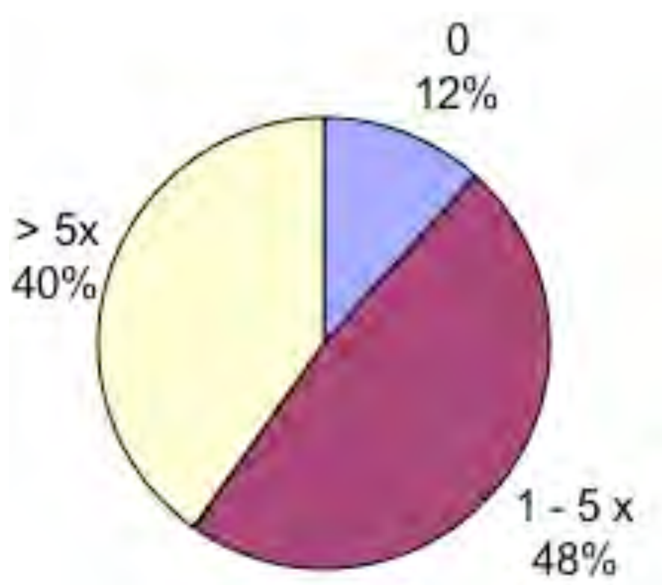

Figure 19. Respondent exposure to THL operation.

12.1.2 Pilot Survey Statements

#	Statement	Category
1	If cleared to depart from the runway, I will proceed through illuminated red Takeoff Hold Lights.	Comprehension
2	I interpret Takeoff Hold Lights turning off as clearance to take off.	Comprehension
3	I have observed Takeoff Hold Lights activate in response to traffic at least once.	Demographics
4	I have seen Takeoff Hold Lights activate on more than five occasions.	Demographics
5	I found the Takeoff Hold Lights were **not** conspicuous enough to serve their intended purpose.	Effectiveness
6	Takeoff Hold Lights operation was consistent with my clearance.	Effectiveness
7	My verbal response time to clearances increased due to Takeoff Hold Lights.	Suitability
8	My ability to complete normal cockpit duties was impeded by Takeoff Hold Lights.	Suitability
9	Takeoff Hold Lights enhanced my situational awareness.	Acceptance
10	I thought that the Takeoff Hold Lights were not functioning.	Effectiveness
11	The Takeoff Hold Lights were **on** when they should have been off.	Effectiveness
12	The Takeoff Hold Lights were **off** when they should have been on.	Effectiveness
13	I was able to distinguish between Takeoff Hold Lights and end of runway centerline lights.	Effectiveness
14	I was compelled to continuing [sic] holding or to stop if rolling when I saw the Takeoff Hold Lights illuminate red.	
15	The Takeoff Hold Lights were distracting from my view on final approach to the parallel runway.	*Suitability*
16	I know of runway conflicts that Takeoff Hold Lights would have helped.	
17	Takeoff Hold Lights will help to reduce the number of runway incursions.	Acceptance
18	I would recommend additional implementations of Takeoff Hold Lights.	Acceptance

Table 4. Pilot survey statements.

Table 11 reproduces the statements on the pilot survey. Each surveyed pilot was asked to indicate their agreement or disagreement with the statements, except that pilots who indicated never having seen THLs in operation (statement 3) were instructed to skip statements about their judgment of how well THLs worked (statements 4–15).

12.1.3 Pilot Survey Results

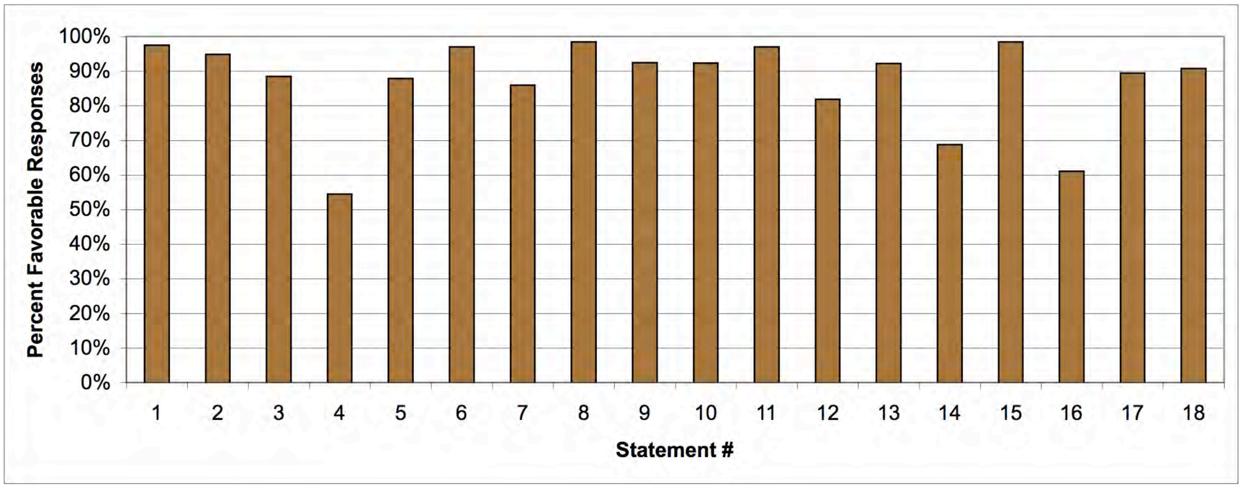

Figure 20. Percent favorable responses by survey statement number.

Figure 28 shows the fraction of favorable responses for each survey statement number. Note that not all 18 statements judge the comprehension, effectiveness, acceptance, or suitability of THLs: Statements 3 and 4 indicate how many times the pilot respondent has seen THLs operate. Statement 14 indicates that the pilot respondent saw THLs in operation that compelled them to stop. Statement 16 indicates that the pilot respondent personally knows of runway conflicts that THLs would have helped. The remaining statements (statements 1, 2, 5–13, 15, 17, 18) all show in excess of 80% favorable responses. All of these statements but one (statement 12) show in excess of 85% favorable responses. (Statement 12, whether the lights were off when they should have been on, may have been answered somewhat unfavorably because the RWSL system was not always turned on.) This is a very high degree of approval from the respondent population.

12.1.4 Pilot Survey Aggregated Results

Responses to specific statements were aggregated into four indices: comprehension, effectiveness, acceptance, and suitability. The comprehension score was based on responses to statements 1 and 2, namely will cross illuminated THLs and THLs off indicate clearance to depart. The effectiveness score was based on responses to statements 5, 6, 10, 11, 12, and 13, namely lights are conspicuous, they are consistent with ATC clearance, lights were not functioning, and lights were off when they should have been on, lights were on when they should have been off, and THLs were distinguishable from end of runway centerline lights. The acceptance score was based on responses to statements 9, 17, and 18, namely THLs enhance situational awareness, will help reduce incursions, and the respondent would recommend additional installations. The suitability score was based on responses to statements 7 and 8, namely verbal response time to clearances and ability to complete normal cockpit duties. The non-aggregated statements (14, 15, 16) were used as checks against the comprehension, suitability, and acceptance scores.

Overall the respondents rated THLs favorably. The large majority of the respondents (96%) understood or comprehended the operating procedures associated with RELs. The effectiveness and acceptance indices, at 91%, were slightly lower than the other two indices. The suitability index was very high at 98%.

Please note that the bar charts in the figures in the following sections are all on an expanded scale starting at 50%. This was done to accentuate the differences between the various scores, but it also has the effect of visually underemphasizing the uniformly very high scores given by the respondents in the various score categories.

12.1.5 Responses by exposure to THLs

The survey indices correlation with exposure to THLs is shown in the next figure. The effectiveness, acceptance, and suitability scores for pilots with no exposure to THLs are missing because those individuals were asked to skip at least some statements pertaining to these scores. If pilots were not exposed to RELs they could not report about how well they worked, so these questions were not relevant to them.

For all pilots who had been exposed to THL operation, increasing exposure increased their positive responses in each of the four categories of statements. The comprehension score for pilots who had not seen THLs in operation is higher than those for pilots who had seen THLs in operation. This may be explained if those neophyte pilots completed the survey because they had just read the training material available on the RWSL website and would be well trained on the basics of THL operation.

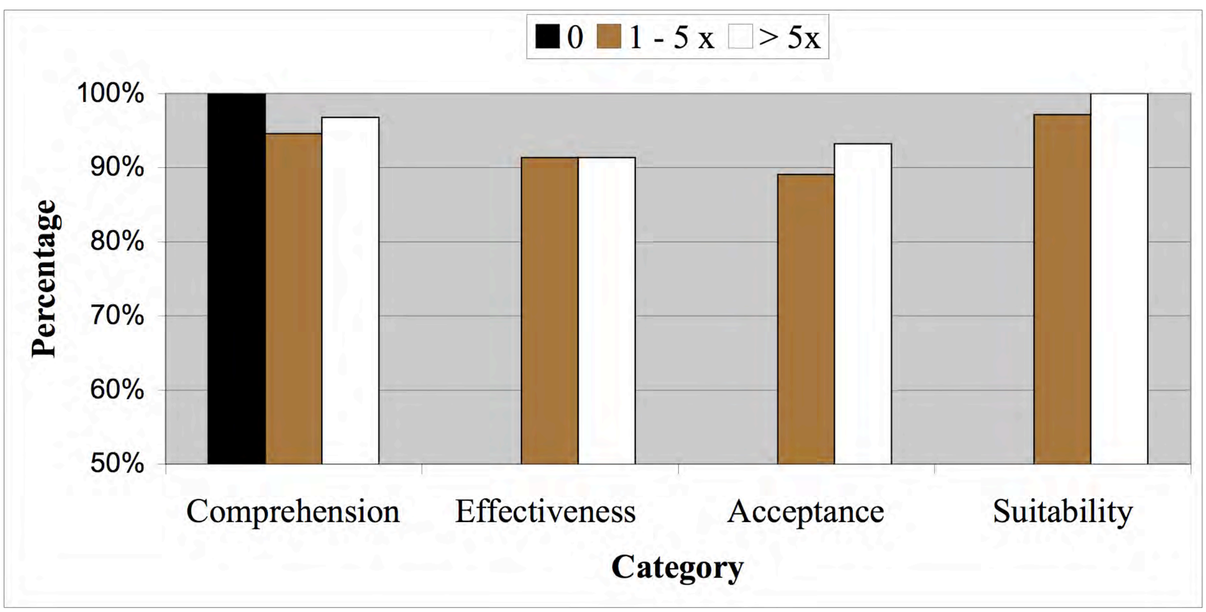

Figure 21. Responses by REL exposure.

12.1.6 Responses by flight experience

The influence of flight experience on the favorability scores for the three indices is depicted in Figure 30. No overall consistent pattern can be discerned in the dependence of the aggregate scores on flight experience.

Comprehension of THL operation did not vary much with flying experience. The effect of flight experience level on perceived operational effectiveness of RELs was relatively small and ranged from 90% to 93%.

Acceptance varied by flying experience. Pilots who had flown 10,000 hours or less responded most positively to RELs with a 96% acceptance level for this subgroup, which is important since most general aviation pilots would fit in this subgroup. For pilots who had flown 10–15 thousand hours, the acceptance level dropped to 87%, and dropped slightly further to 86% for pilots who had flown more than 15,000 hours.

Suitability scores also varied by flight experience. Pilots who had flown 10–15 thousand hours provided an aggregate score of 93% for suitability, while pilots who flew either fewer or more hours gave a suitability score of 100%.

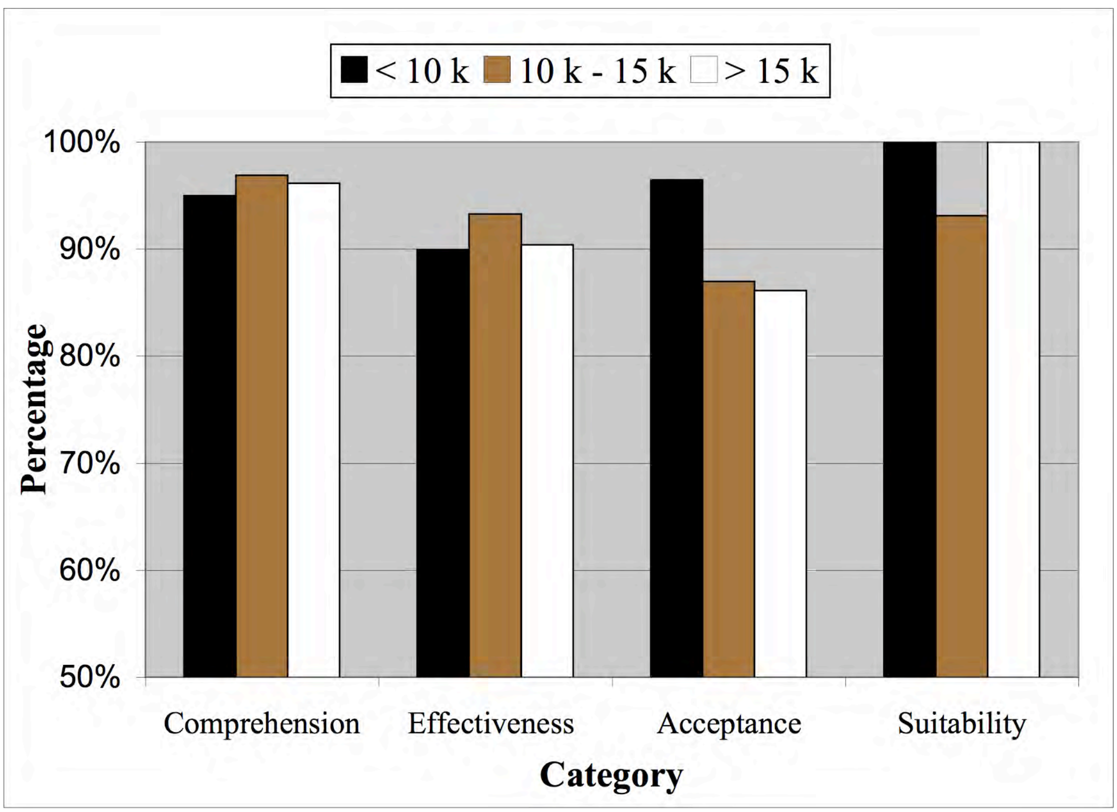

Figure 22. Responses by flight experience.

12.1.7 Responses by airline

Figure 31 shows the category scores for pilots from the two major airlines at DFW, American Airlines (AAL) and American Eagle (EGF), and other airlines and GA pilots in the aggregate. American Eagle pilots consistently rated THLs higher in comprehension, effectiveness, and acceptance than the other airlines. Pilots from all airlines rated THLs very high in suitability.

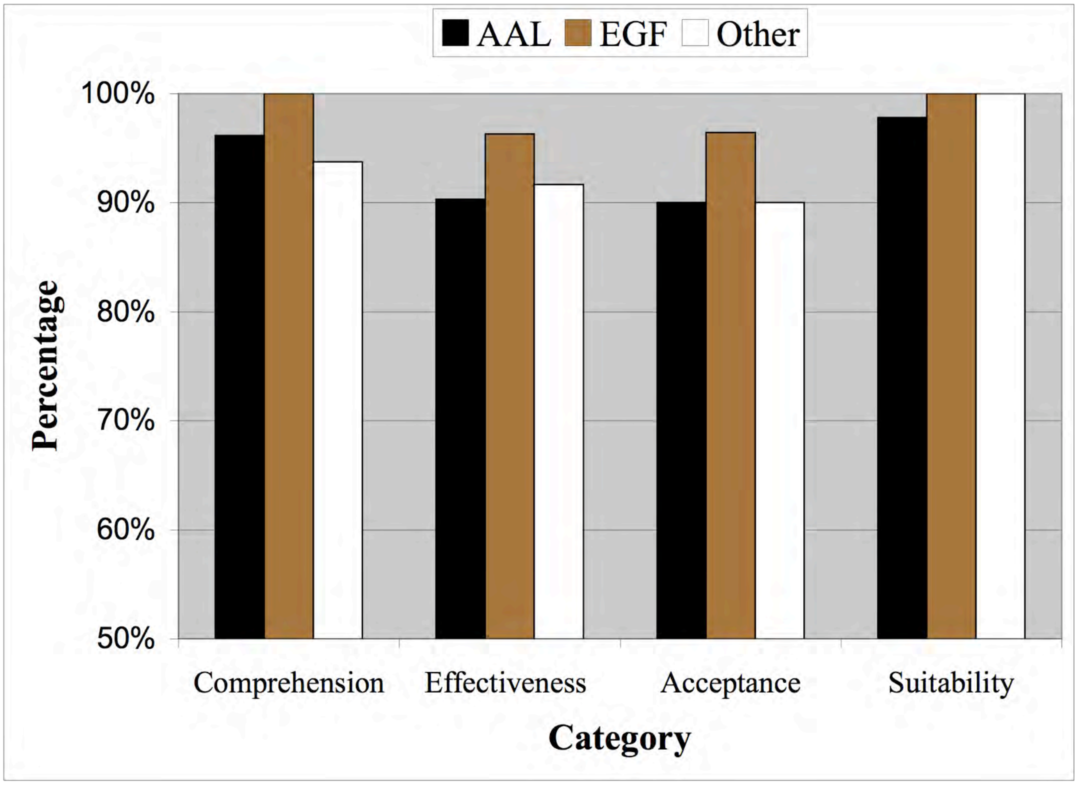

Figure 23. Category scores by airline.

12.1.8 Responses by role

Figure 32 shows the category scores for pilots and co-pilots. Pilots rated THLs higher in the acceptance score than copilots (96% vs. 88%). Co-pilots rated THLs slightly more effective than pilots (93% vs. 91%). Pilots and co-pilots had similar scores for comprehension and suitability.

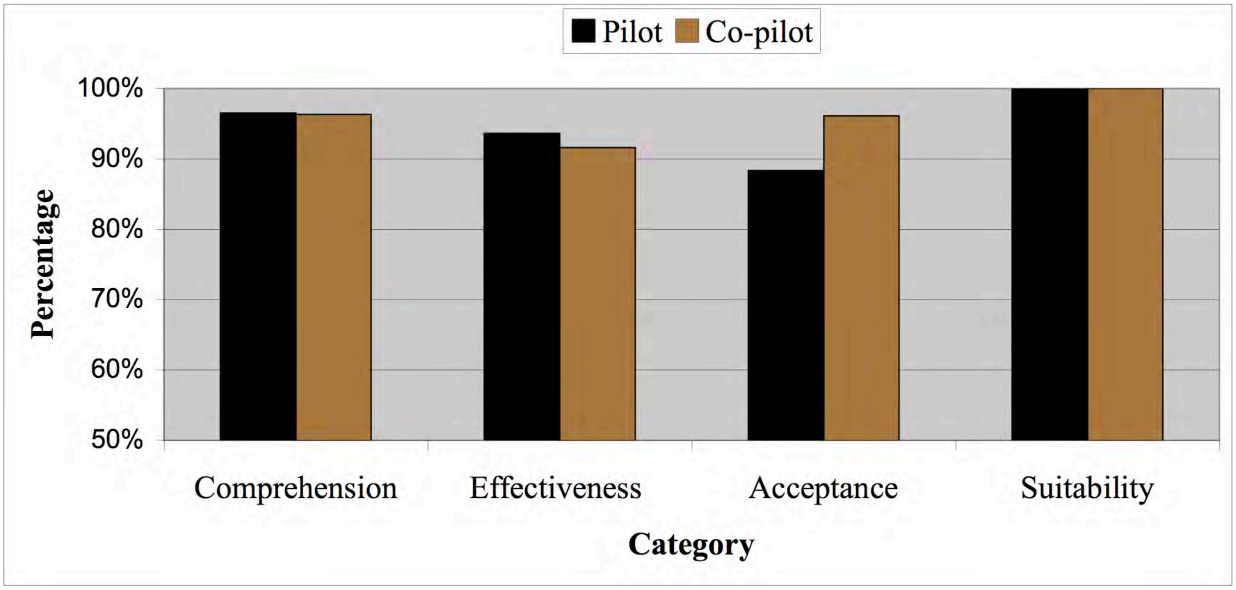

Figure 24. Category scores by cockpit role.

12.1.9 Pilot Survey Correlations

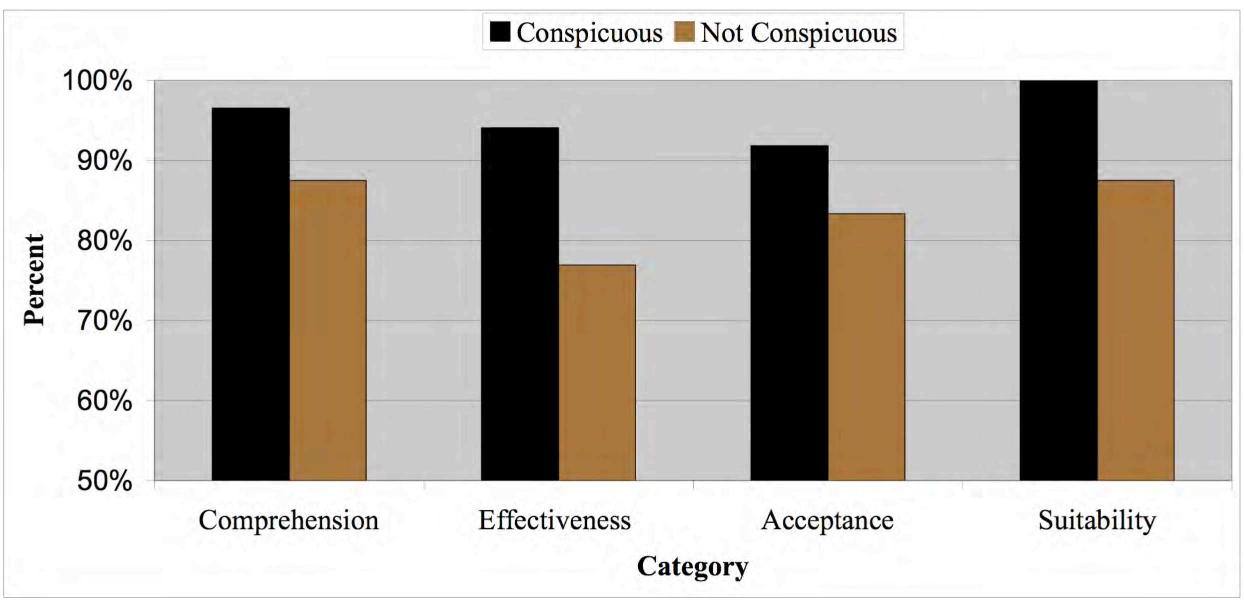

Figure 25. Category scores by answer to question 5, are the THLs conspicuous.

The strongest and most uniform correlations between responses to individual questions and the four category scores were for statements 5 and 13. Both statements relate to effectiveness of the THLs based on their visual appearance. Statement 5 is about whether the THLs were conspicuous, and statement 13 is about whether the THLs are visually distinct from the end of runway centerline lights.

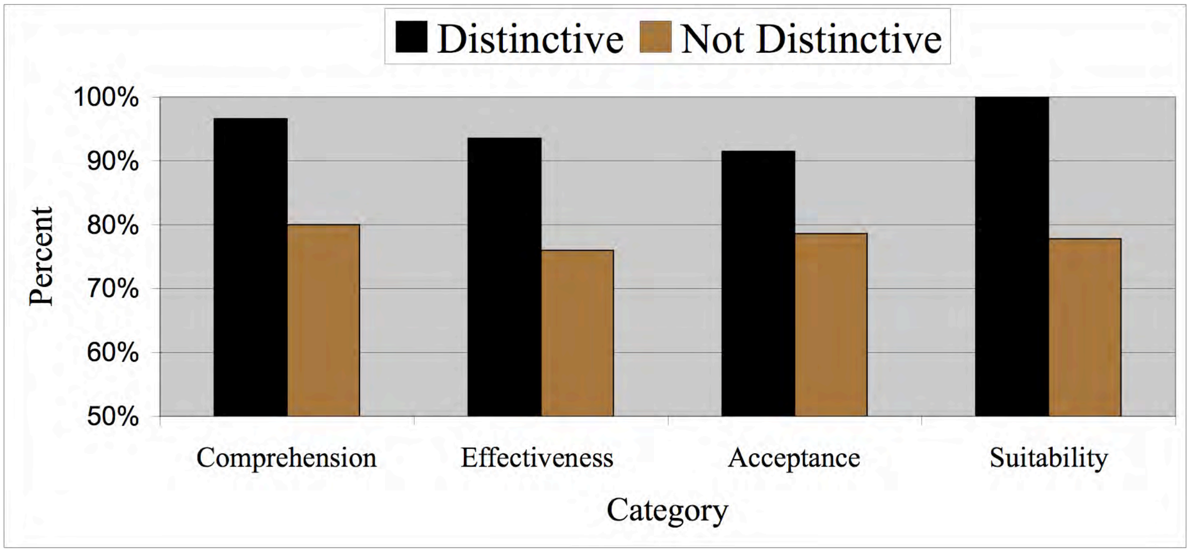

Figure 26. Category scores by answer to question 13, are the THLs distinctive from the end of runway centerline lights.

Based on these two correlations, it is likely that improving THL conspicuity and distinctiveness will result in greater understanding and approval of THLs in these four categories. Indeed, the current FAA recommendation for the THL configuration is to extend the array of lights by 500 feet (five fixtures) closer to the aircraft in position for takeoff, and to use a double row of lights, 6 feet on either side of the runway centerline, instead of the single row, 2 feet on one side of the centerline used for the operational evaluation on 18L/36R at DFW. Furthermore, it is likely that THLs in the future will be put on different circuits from the RELs, and their brightness will therefore be independently adjustable. In particular, THLs may be set to a brighter illumination at night, when they are otherwise somewhat subject to washing out in the light of the runway centerline lights.

12.1.10 Additional survey comments

Pilot respondents were also encouraged to give feedback in the form of additional comments entered near the end of the survey form. A little more than half of the respondents did so. This is an atypically large fraction for such comments, indicating that the respondents were well motivated to provide detailed feedback.

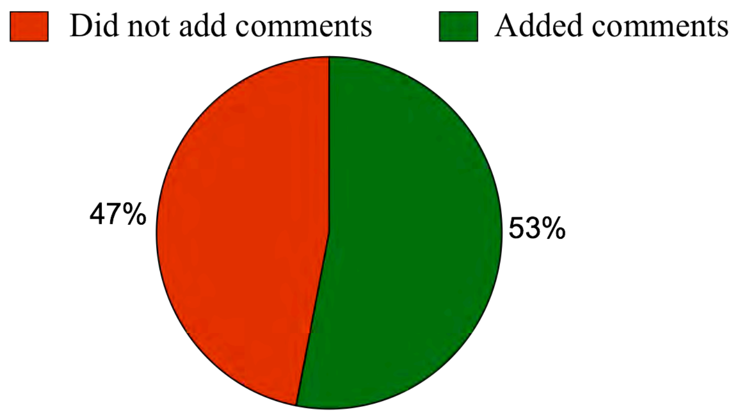

Figure 27. Fraction of pilots who entered comments in the survey.

The comments were all read and classified as positive, negative, referring to lighting configuration, or possibly irrelevant to the evaluation. Most of the comments were positive, representing a high level of support for the THL concept, and calling for them to be fielded at additional airports. About a sixth of the comments discussed the lighting configuration. Three of these comments called for a "cross bar", where the THL fixtures are arranged across the

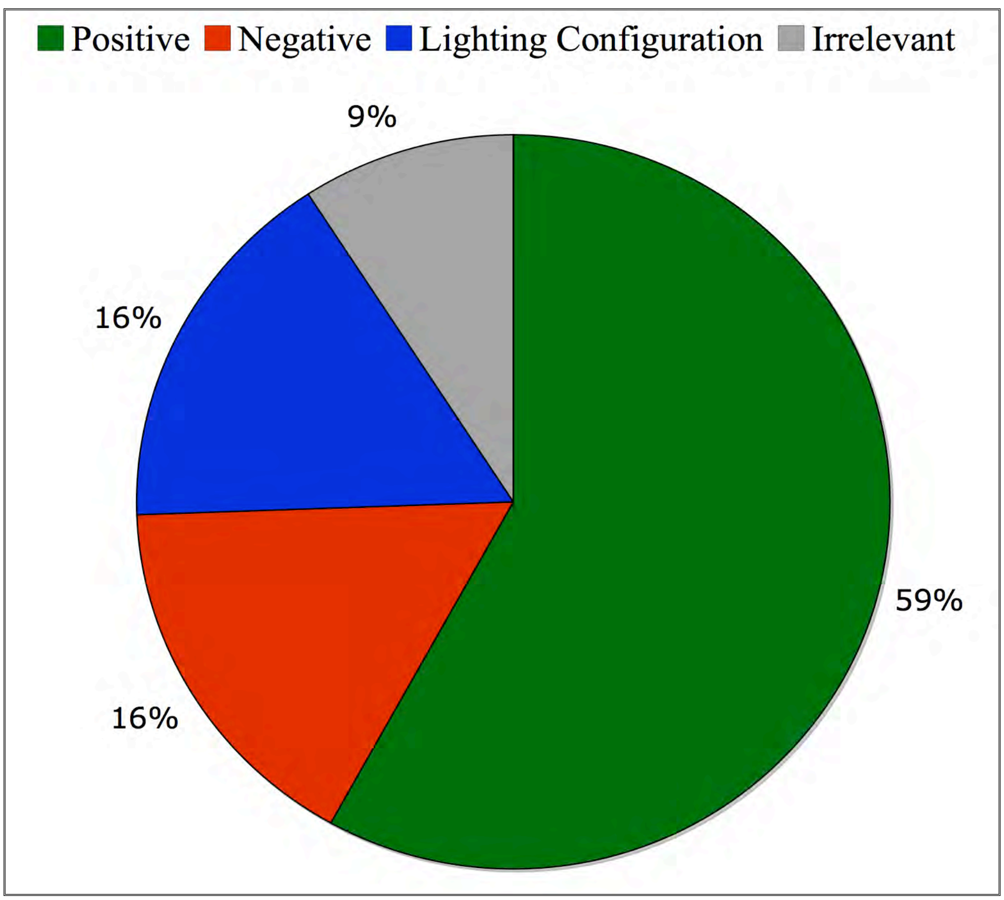

Figure 28. Type of survey comment.

runway instead of along it. About a sixth of the comments were negative, mostly about the timing of the light operation or about THL conspicuity and proximity. It can be expected that at least some of these negative comments would likely be addressed by the proposed new standard for THL lighting configuration mentioned above.

There was a strong correlation between the type of survey comment and the category scores for the rest of the survey. Those respondents providing a negative comment rated the THLs lower in comprehension, effectiveness, acceptance, and suitability. Those respondents providing a comment on the THL lighting configuration rated the THLs lower in effectiveness, but not lower in comprehension, acceptance, or suitability.

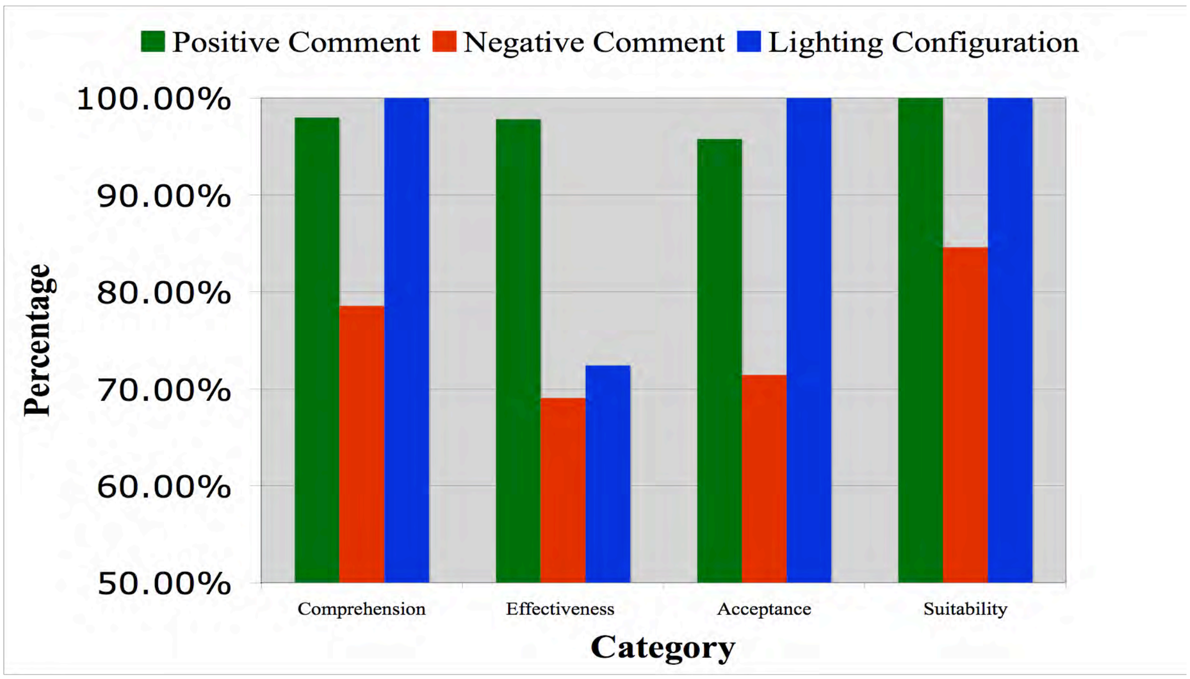

Figure 29. Correlation between category scores and comment type.

12.1.11 Pilot survey synopsis

In aggregate, the pilot survey results were highly favorable, over 90% in aggregate. The scores were near or above 90% as a function of exposure, airline, and role. They were above 85% as a function of experience. Comprehension ranged from near 80% to 100%. Effectiveness ranged from near 70% to 96%. Acceptance ranged from 71% to 96%. Suitability ranged from 77% to 100%. The scores were measurably lower when a negative comment was given or when the pilot rated THLs as inconspicuous or indistinct.

RELs and THLs are designed to provide overlapping safety benefit for a variety of runway usage scenarios. No observer noticed any deleterious effects of the use of THLs in combination with RELs, which validates this core design principle of RWSL.

12.2 Vehicle Operator Survey

Vehicle operators permitted to drive on and across runways were surveyed for their reaction to THL operation. The pilot and vehicle operator surveys were identical. Because only seven vehicle operator surveys were returned, however, the results are statistically insufficient to merit reporting. Vehicle operators are not subject to holding on the runway when the THLs are illuminated, however, so this lack of sufficient survey responses is not inappropriate.

13 Conclusions

13.1 Main Results

The operational evaluation of takeoff-hold lights at DFW clearly indicates that:

- THLs work technically, operationally, and conceptually.
- Pilots perceive THLs to be a safety aid that could help reduce runway incursions.
- THLs do not impose significant workload on pilots or controllers.
- THLs do not interfere significantly with normal, safe operations.
- THLs do not cause a significant increase in controller-pilot communications.
- The vast majority of the pilots surveyed would recommend the installation of RELs at other airports.

These results are consonant with the results obtained previously for RELs.

13.2 Recommendations for Future Work

There are significant conclusions that indicate further work is required:

- THL operation for runways that cross other runways requires crossing-runway algorithms that cannot be tested at DFW. Testing the THL crossing-runway algorithms is being planned for Chicago O'Hare International Airport (ORD). This work should be continued in order to test the THL operational concept fully.
- Correct operation of THLs requires excellent surveillance. The ASDE-X prototype at DFW was improved to improve its performance, and algorithmic enhancements were introduced into RWSL to reduce the frequency of false tracks, track splits, incorrect velocity estimates, and incorrect altitude measurements. These enhancements should be migrated into the ASDE-X baseline so that all consumers of ASDE-X data, including controllers and the ASDE-X safety logic, would benefit from the improved surveillance.
- The RWSL state machine should be augmented to identify aircraft taxiing or other vehicles driving on the runway and modify the REL and THL logic in accordance with this identification.
- THL conspicuity, distinctiveness, and configuration are the most frequent issues identified by pilot survey respondents. These issues have been investigated previously, and in fact that investigation led to an improved THL lighting configuration with five more fixtures nearer the holding position on the runway for departures, and with two rows of THL fixtures six feet on either side of the runway centerline. This new

configuration should be installed at DFW and used in further installations to improve pilot acceptance of THLs. Furthermore, THLs should be placed on separate circuits from the RELs to allow the option of higher current settings at night than used for the RELs.

- The pilot survey results were largely reducible to four indices: comprehension, effectiveness, acceptance, and suitability. The list of statements should be reviewed and possibly expanded to include other concepts that need to be studied. Furthermore, some questions could be added to allow further internal validation of the survey results. Additionally, a new, more targeted survey could be developed for repeat evaluators.

- The RWSL website served as a useful information release method and as an electronic survey host. The structure of the website could be improved to incorporate new elements such as a What's New page, Frequently Asked Questions, and Testimonials. The training could be enhanced and an online quiz employed to improve pilot understanding of the purpose and timing of the light operation.

Addressing the above issues will significantly enhance RWSL operational compatibility and improve pilots' experience with THLs and their perception about their effectiveness and utility.

14 Summary

Runway status lights shown directly to pilots and vehicle operators offer the potential to reduce runway incursions and runway conflict accidents by increasing overall situational awareness of the dynamic runway environment. The operational evaluation phase of RWSL was a live test with actual traffic and a limited deployment of a field lighting system, with a presence in both the operational tower and the observation tower in order to prove the runway status lights concept. The operational evaluation test period provided critical technical performance and operational feedback information required to assess the suitability and correctness of operation of RWSL in providing an important safety function. The operational evaluation proved the RWSL concept meets the key high-level requirements; that the runway status lights operate automatically, that no controller action is required for their operation, that the lights accurately depict runway status to pilots and vehicle operators, and that the lights do not interfere with normal safe surface operations. The operational evaluation constitutes for the takeoff-hold lights a major phase of the RWSL research and development program culminating in a prototype deployment. The results of the operational evaluation will serve as validation to continue the deployment of runway status lights at other busy airports in the NAS and for further evaluation at DFW.

15 References

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